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Methods for the Analysis of Preservative-Treated Timbers.*

1. The Determination of Arsenic.

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Summary.

For the purpose of studies concerning the penetration of arsenic in certain treated timbers, methods have been developed for estimating (i) quantities of the order of 0.2 to 0.4 per cent. which occur in the outside layers of treated timber, and (ii) quantities of 0.05 per cent. or less which occur in the timber beyond the outside layer. The method described has been adapted from that described in the *Analyst* (1930) by the Sub-committee on Arsenic of the Society of Public Analysts. Fundamentally, this method consists of two processes:—(*a*) wet combustion to destroy organic material under conditions which reduce to a minimum the possibility of loss of arsenic by volatilization, and (*b*) separation of arsenic from other mineral matter by distillation under standardized conditions which result in a small but constant blank. The recovery of arsenic added to wood powder has not been less than 98 per cent.

1. Introduction.

For the purpose of studying certain methods of preservative treatment of green wood and for preparing specifications concerning these, it is necessary to have convenient and accurate methods for the determination of arsenic in the treated wood. The required methods may be divided into two types, viz., (i) for the determination of the larger quantities which are found in the outside layers of a piece of treated timber, and (ii) for the determination of the smaller quantities found in the wood beyond the outside layer.

The larger quantities mentioned above have been found by experience to be of the order of 0.2 to 0.4 per cent., or 20 to 40 milligrams of As_2O_3 per 10 grams of oven-dry wood. The smaller quantities are of the order of 0.05 per cent. or less. Whichever quantity has to be determined, two main problems must be dealt with; these are (i) the destruction of the organic constituents of the wood without loss of arsenic, and (ii) the separation of the arsenic from the inorganic constituents in the residue so that its estimation may be made without interference.

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2. The Outline of Investigation.

Of the numerous published methods which might be used for the determination of larger quantities of arsenic, most have been developed for the determination of 50 mgms. of As_2O_3, or more, in an aliquot part of a sample. Consequently, this amount is generally only a fraction of the total arsenic present in the sample taken for analysis, and errors introduced by reagents used during the wet combustion are therefore proportionately reduced and are frequently of little consequence. Volumetric methods for the ultimate estimation of arsenic are generally employed but, with these, the question of blanks has always to be considered. In routine determinations for which the method at present under discussion was required, it is desirable to use a method which will always give either a constant blank or none at all. It has been found that a blank of some sort is unavoidable in the determination of arsenic in wood. One source of this is the inorganic fraction of a wood sample, but serious errors due to this may easily be overcome by employing methods for the separation of arsenic prior to titration. Other sources of blanks are the reagents employed both in the wet combustion and in any subsequent treatment such as distillation. By using chemically pure reagents and a standardized procedure, the blank from such sources may be reduced to a minimum and, further, to a constant quantity. Under ordinary circumstances, the influence of a blank may be considerably reduced by using larger quantities of wood and subsequently determining the arsenic in an aliquot part of the combustion residue. In the case of penetration studies of arsenic-treated wood, successive layers are removed from a sample and the quantity of wood available is frequently limited. In the present instance, it was necessary to be able to determine the arsenic with reasonable accuracy in a sample not exceeding 20 grams of wood.

In the determination of smaller quantities of arsenic, such as would be found in wood beyond the outside layer, the ultimate estimation is generally made by means of colorimetric or stain methods. Such methods require (i) the absence of a blank caused by reagents or substances in the wood, and (ii) a minimum of interference to the uniform generation of arsine. As the quantities to be estimated in the present instance were appreciable rather than minute (i.e., considerably greater than parts per million), the question of sampling needed consideration as well.

3. Experimental Procedure.

For the purpose of studying the various known methods for the determination of arsenic, the wood of karri (*Eucalyptus diversicolor*) was used throughout, because this wood when treated was to be the main subject of the investigation for which the method of analysis was desired.

Chemically pure reagents were used throughout, and, in the study of methods for the determination of the smaller quantities of arsenic, guaranteed arsenic-free materials were employed. All glassware was of Pyrex make and was thoroughly pickled by means of hydrochloric acid before use.

The investigation involved a study of methods of preparation of samples, destruction of organic material, separation of arsenic from other mineral substances, and estimation of arsenic.

For samples used in the determination of the larger quantities of arsenic, it was found that either rasped or finely milled samples were satisfactory from the point of view of accuracy, but that the use of the finer material greatly facilitated the destruction of organic material. The size of the sample which could be most conveniently handled was 10 grams. Larger samples, up to 20 grams, were employed at times, but these required the use of larger Kjeldahl flasks and larger quantities of reagents. For the smaller quantities of arsenic, it was found to be preferable to take at least 1 gram of wood in a finely divided condition. This was attained by means of an impact mill which was carefully sealed to avoid losses in the form of dust. The finely divided wood was discharged from the mill into a funnel over which was stretched a piece of closely woven cloth.

Methods for the destruction of organic matter and separation and estimation of arsenic were studied in relation to the recovery of arsenic obtained, agreement between duplicates, the interference with arsenic separation, the interference with arsenic estimation, and the attention required in routine determinations.

Several known methods of wet combustion were examined. For these, the following oxidizing mixtures were used:—

- (*a*) Potassium chlorate, nitric acid, and sulphuric acid (1).
- (*b*) Nitric acid saturated with bromine, and sulphuric acid.
- (*c*) Nitric acid and sulphuric acid with and without copper sulphate as a catalyst.
- (*d*) Nitric acid alone (2).

An examination of methods employing perchloric acid had been contemplated, but no reagent of suitable quality was procurable at the time. Apart from the above-mentioned wet combustion methods, dry methods were also examined. These included ignition of the wood at about 400–500°C. after it had been treated in order to convert the arsenic into magnesium pyroarsenate, and also fusion of the wood with caustic potash. Attempts to avoid the necessity of destroying the organic material were made by employing a method for the direct distillation of the arsenic.

The estimation of arsenic in the wet combustion residues was attempted by using the iodimetric titration method following reduction of the arsenic acid with potassium iodide or sulphurous acid, but substantial blanks and recurring end-points were experienced. Apart from this, the recovery of arsenic, added in known quantities to the wood, was not always consistent, and was generally only 90 per cent. or less. From the experience gained, it was concluded that the arsenic should be separated from the mineral constituents of the wood before titrimetric methods could be used.

Separation of arsenic was attempted by distillation of arsenic as arsenious chloride (3) (4), by precipitation as sulphide (5), and by precipitation as magnesium pyroarsenate (6) (2). In all cases, the arsenic was estimated volumetrically using standard iodine solution (7).

From the experiments using the foregoing methods, it was concluded that, for the quantities under consideration, the procedures examined were not suitable, and that more standardized conditions were necessary before a satisfactory recovery of arsenic and a negligible or constant blank could be obtained. Furthermore, some of the methods were long and tedious, and were not suitable for routine analyses of several samples at the same time.

The method for the determination of arsenic in dyestuffs described by the Sub-committee on Arsenic of the Society of Public Analysts (8) appealed to the author because it had been designed to meet with two essential requirements, viz.:—

(*a*) Wet combustion under conditions which reduced to a minimum the possibility of loss of arsenic by volatilization.

(*b*) Separation of arsenic from other mineral substances by distillation under standardized conditions.

Although this method had been developed for estimating minute quantities, experimental work showed that it was adaptable to the determination of the larger quantities required by the conditions of this investigation. In addition, the apparatus for the distillation stage was of simple, compact construction, such as would be suitable for conducting several distillations at the one time. After a considerable amount of experimentation, the methods described below for the determination of both the larger and smaller quantities of arsenic were adopted.

4. Methods Adopted.

A. For the Determination of Larger Amounts of Arsenic (20 to 40 mgms.).

(i) *Preparation of Sample.*—The sample is cut into thin sections by means of a chisel. The thin sections are fed into a laboratory impact-mill, the base of which is blanked off so that the wood can escape only through a hole tapped in the side of the mill casing. The escaping wood powder is caught in a metal funnel which is fitted by the stem to this hole, and which is covered at the wide end with a tightly fitting cloth of fine texture. In this manner, no losses of dust occur. The sample is used as obtained, i.e., without being sifted. (Measurements have shown that approximately 70 per cent. of the wood powder will pass through a sieve of 100 meshes to the inch.) In the absence of a suitable mill, samples may be prepared by using a rasp. Such samples are quite suitable for the determination of larger quantities of arsenic, although, on account of their coarseness, they do not lend themselves so readily to the wet combustion treatment.

(ii) *Wet Combustion of Wood.*—For the sake of economy in the amount of wood used for each determination, the actual sample (approximately 10 gms.) is dried in an air oven at 105°C. and then weighed by difference into a Kjeldahl flask (500 ml. capacity). To the flask are added water (2 ml. per gram of wood taken) and concentrated nitric acid (5 ml. per gram of wood taken). The contents of the flask are thoroughly mixed, the reaction controlled, if necessary, by cooling the flask under running water, and the mixture is left to stand until the

reaction subsides, or, preferably overnight. (*Note.*—The procedure of leaving the mixture to stand overnight is not absolutely necessary, but is convenient for routine work where a large number of analyses are undertaken. In addition, it results in a considerable amount of disintegration of the wood, thereby reducing the amount of attention required during the subsequent operation.) Next day, or when the reaction subsides, and after thorough mixing, the flask is partially closed by means of an empty reversed calcium chloride tube, and the contents are gently heated over a small gas flame until the reaction and evolution of brown nitrogen oxide fumes subside (usually in 20 to 30 minutes). To the flask are then added (without cooling) concentrated nitric acid (5 ml. per gram of wood taken) and concentrated sulphuric acid (1.5 ml. per gram of wood taken). The heating over a small flame is continued until the evolution of brown nitrogen oxide fumes subsides. The neck and sides of the flask are washed down with a jet of hot distilled water, and the heating is then intensified. Finally, a stage is reached where charring occurs. At this stage and before copious fumes of sulphur trioxide appear, the gas flame is lowered slightly and concentrated nitric acid (1 ml.) is added drop by drop. (This procedure is most conveniently carried out by means of a small pipette, the stem of which is bent at an angle convenient for manipulation in the fume cupboard. The acid may be fed to the flask through the calcium chloride tube stem, and, if added slowly, it will run down the side of the flask and no violent spluttering will occur.) After the addition of nitric acid, the heating is continued until the brown nitrogen oxide fumes disappear. If the residue is still somewhat coloured, another small quantity of nitric acid is added, and the procedure is repeated until the hot residue is colourless, faintly straw-coloured, or faintly green. After cooling somewhat, distilled water (75 ml.) is added, and the mixture is boiled until white sulphur trioxide fumes just appear. This procedure is repeated a second time to ensure that nitric acid is expelled. The residue in the flask is then thoroughly cooled.

(iii) *Distillation of Arsenious Chloride.*—The apparatus used for this purpose is shown in Fig. 1. It consists of the Kjeldahl flask (A) fitted by means of a rubber stopper with a pipette-shaped air condenser (C) to which is sealed a drop funnel (B). The bulb of the condenser is equipped with a splash-head tip which reduces the possibility of liquid being splashed up and sucked back into the flask. The tip of the air condenser dips just below the surface of dilute nitric acid (1 : 5) contained in the Erlenmeyer flask (D). The flask stands in a shallow tray (E) which contains water and ice. The rubber stoppers, before use, are steeped in dilute hydrochloric acid and then thoroughly scrubbed with soap and hot water. Fig. 1 shows an arrangement of apparatus for carrying out six distillations at the same time.

For the distillation of arsenious chloride, water is added to the residue in the Kjeldahl flask in a quantity equivalent to 7 ml. for every 10 ml. of concentrated sulphuric acid used in the wet combustion, and the mixture is thoroughly cooled. To the flask are then added together, dry common salt (7.5 gm.), hydrazine sulphate (1 gm.), and potassium bromide (1 gm.), and the flask is immediately fitted with the air condenser, the drop funnel stop-cock being closed. The condenser tip dips below the surface of 120 ml. of 1 : 5 nitric acid contained in the

Erlenmeyer flask (D). Concentrated hydrochloric acid (80 ml.) is slowly added to the Kjeldahl flask through the drop funnel, and the contents are then thoroughly mixed. Heat is now gently applied to the bottom of the flask by means of a small gas flame so that a steady controlled stream of hydrochloric acid gas is produced. The heating is continued until most of this gas is evolved. This point is indicated by a strong tendency for the mixture in the receiver to be sucked back and by the presence of steam at the top of the condenser (i.e., increase in temperature at the top of the condenser). The distillation is stopped and the suck-back controlled by occasionally admitting air through the drop funnel stop-cock. When the contents of the flask have cooled sufficiently to avoid violent evolution of gas, more concentrated hydrochloric acid (40 ml.) is added from the drop funnel, and the distillation is continued over a somewhat larger gas flame. When this stage is completed, the drop funnel may be left open to avoid a suck-back, the condenser is disconnected and washed through with distilled water, the washings being added to the distillate in flask D. The contents of this

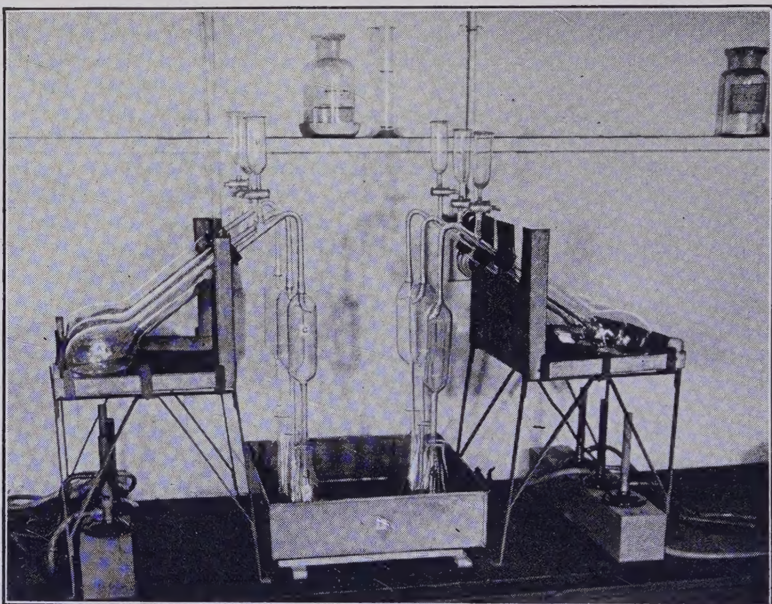

FIG. 1.—Showing set-up of apparatus for six simultaneous distillations for arsenious chloride.

flask are boiled almost to dryness on a hot plate, the last stages of heating being carefully controlled. Distilled water (100 ml.) is added and the boiling repeated. Then sulphuric acid (10 ml. of 1:1) and more water (50 ml.) are added, and the mixture is boiled until white sulphur trioxide fumes appear, but strong fuming must be avoided.

(iv) *Titration of arsenic.*– The residue in the flask is then diluted to 150 ml. with distilled water, postassium iodide (1.5 gm.) is added, and the mixture boiled until the iodine colour is destroyed or nearly so. (The volume should not be reduced to below 50 ml.) After cooling

under running water and diluting to 100 ml. with distilled water, the remaining iodine colour, if any, is surcharged by the addition of a few drops of N/25 sodium thiosulphate solution. The mixture is then made slightly alkaline with strong sodium hydroxide solution (approximately 20 ml. of 33 per cent.) using phenolphthalein as indicator, then just acid with sulphuric acid (1 : 20), and finally cooled. The volume is adjusted to approximately 200 ml., sodium bicarbonate (5 gm.) added, and the arsenic titrated with N/25 iodine solution (which has been standardized against standard arsenic solution), using starch indicator (2 ml. of 0.5 per cent.) only towards the end. The end-point colour, which is permanent, is influenced by the concentration of sodium sulphate, and is of a purple colour rather than the usual starch-iodide blue.

B. For the Determination of Smaller Amounts of Arsenic (0.5 mgm. or Less).

(i) *Preparation of Samples.*—All samples intended for the estimation of the smaller amounts of arsenic are prepared in the form of fine wood powder by means of the laboratory impact mill. The use of coarser material is not recommended because of the difficulty of selecting representative samples weighing only 1 gram.

(ii) *Wet Combustion of Wood.*—Approximately 1 gram of oven-dry wood powder is weighed into a Kjeldahl flask (200 ml.). Water (4 ml.) and nitric acid (10 ml.) are added, and the mixture is left to stand for some time or preferably overnight in routine work. (The flask is covered by means of an inverted empty calcium chloride tube.) The mixture is next heated over a small flame until the evolution of nitrogen oxide fumes subsides and the mixture boils gently. Then, without cooling, nitric acid (5 ml.) and arsenic-free sulphuric acid (5 ml.) are added, and the heating continued until the reaction subsides. The sides of the flask are washed down with a jet of hot distilled water, and the heating is intensified and continued until charring occurs and white fumes of sulphur trioxide commence to appear. The gas flame is lowered, and nitric acid is added a few drops at a time by means of a pipette until the hot fuming residue is colourless, faintly straw-coloured, or faintly green. After cooling slightly, water (25 ml.) is added, and the mixture boiled down until copious white sulphur trioxide fumes appear. A second addition of water (25 ml.) is made, followed by a second boiling in order to ensure that all the nitric acid is expelled.

(iii) *Estimation of Arsenic.*—The residue is transferred to a measuring flask of convenient size (100-200 ml.), and the Kjeldahl flask washed out several times with distilled water, the washings being added to the measuring flask. The contents of the latter are cooled and made up to volume with distilled water. An aliquot, the size of which is guided by preliminary trial tests, is measured by means of a pipette into the Douzard apparatus.

For the estimation of arsenic, the following reagents are required:—

A. Sulphuric Acid 1 : 4, containing 100 grams of sodium chloride per litre.

B. Iron alum, 84 grams of ferric ammonium sulphate, and 10 ml. of solution A per litre.

C. Stannous chloride, 40 grams of stannous chloride dissolved in concentrated hydrochloric acid to make a final volume of 100 ml.

D. Lead acetate, 1 per cent. in water, the solution being cleared by the addition of a few drops of acetic acid.

E. Mercuric bromide, 1 per cent. in alcohol.

To the Douzard apparatus are added the aliquot sample previously mentioned, then sulphuric acid (Solution A) (11.5 ml. less the amount contained in the sample aliquot), iron alum (2 ml. of Solution B), stannous chloride (1 ml. of Solution C) and water to make the total volume 40 ml. Lead acetate is charged into the purification bubblers, and a strip of filter paper, impregnated with mercuric bromide and cut to a standard size, is placed in the side tube. Arsenic-free zinc, cut from ¼-inch rods to a standard length of about ¼ inch, is now added to the apparatus in the following quantities based on its surface area:—

If not previously used	15 gms.
If previously used once	10 gms.
If previously used twice	8 gms.

The head of the Douzard apparatus is immediately fitted, and the generation of hydrogen and arsine is allowed to continue for a period of one hour, after which the mercuric bromide paper is removed, coated with paraffin wax, and compared with standard strips prepared by using known quantities of arsenic under identical conditions. Generally, the most satisfactory stains are those representing 0.003 to 0.007 mgms. of As_2O_3. In comparing the strips, both intensity and length of stain must be taken into account.

5. Results.

In the determination of arsenic added to wood in known quantities of the order of 20 to 40 mgms. per 10 grams of wood, the procedure outlined in the foregoing pages gave results which are set out in Table 1. The blank in the final titration has been found to be consistently 3 or 4 drops or 0.15 ml. of approximately N/25 iodine, and this is equivalent to 0.3 mgm. of As_2O_3.

TABLE 1.—SHOWING RECOVERY OF ARSENIC ADDED IN KNOWN QUANTITIES TO THE WOOD OF KARRI (*E. diversicolor*) USING THE METHOD DESCRIBED.

As_2O_3 added to 10 gms. of wood (mgm.).	Titres with three separate determinations (ml. of approx. N/25 iodine).	Average Titre (ml.).	As_2O_3 found (mgm.).	Blank (mgm. As_2O_3).	As_2O_3 recovered (mgm.).	Recovery (%).
20·0	10·59 10·56 10·57	10·57	19·9	0·3	19·6	98·0
40·0	21·10 21·20 21·13	21·14	39·8	0·3	39·5	98·7

The above results were obtained when hydrazine sulphate and potassium bromide were used as reducing agents. It is of interest to record that earlier experiments using cuprous chloride (2 grams) as the

reducing agent yielded some excellent results, but only when the reagent was used immediately after the bottle was opened. After it had been kept for some time in the laboratory, the recoveries of arsenic added to wood were not satisfactory. Table 2 shows the results obtained during the earlier experiments with this reagent.

TABLE 2.—SHOWING RECOVERY OF ARSENIC ADDED TO THE WOOD OF KARRI (*E. diversicolor*) USING CUPROUS CHLORIDE AS THE REDUCING AGENT IN THE DISTILLATION STAGE.

As_2O_3 added to 10 gms. of wood (mgm.).	Titres with three separate determinations (ml. of approx. N/25 iodine).	Average Titre (ml.).	As_2O_3 found (mgm.).	Blank (mgm. As_2O_3).	As_2O_3 recovered (mgm.).	Recovery (%).
10	5·01 5·00	5·00	10·1	0·3	9·8	98
20	9·81 9·87	9·84	19·9	0·3	19·6	98
30	14·98 14·82	14·90	30·2	0·3	29·9	99·6

After the reagent had been in contact with the laboratory atmosphere for some weeks, the recoveries fell away considerably, the most satisfactory being 96 per cent.

The method as described, except that fresh cuprous chloride was used in the absence of suitable hydrazine sulphate, was used during the early stages of this investigation for the determination of arsenic in fluarised karri sleepers. It is of interest to record some of the duplicate results obtained; these are as follows:—

Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
0·37	0·28	0·21	0·28	0·25
0·37	0·28	0·21	0·28	0·25
0·23	0·27	0·22	0·18	0·28
0·23	0·27	0·22	0·17	0·28
0·32	0·22	0·17	0·26	
0·30	0·24	0·17	0·26	

In connexion with the estimation of small quantities, recoveries of arsenic added to wood in amounts varying from 0.1 mgm. to 0.5 mgm. of As_2O_3 per gram of wood are shown below:—

Arsenic added (mgm.).	Arsenic recovered (blank allowed for).	Recovery (%).
0·0998	0·0978 0·0998	98 100
0·4992	0·4792 0·4892	96 98

6. Acknowledgments.

The author desires to record his appreciation of the assistance rendered by R. A. Bottomley and A. J. Watson during the course of this study.

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Further Observations on Glycerine—Boric Acid Dressings for Fly-Struck Sheep.

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1. Introduction.

In an earlier paper (this *Journal,* **8**, 161, 1935), it was shown that glycerine—boric acid preparations possessed useful properties as dressings for treating fly-struck sheep. Further work was, however, required, both to test the conclusions already reached and to improve the dressings in consistency, in antiseptic action, and in economic production by dilution and by simplifying methods of preparation. The present paper records recent work with the original, and with modified, dressings.

2. Chemical and Physical Characters of the Dressings.

Two main groups of preparations have been used:—

(i) Those preparations in which boric acid is dissolved in glycerine without strong heating. The typical member of this group was described in our previous paper as glyceroboric acid, and this name is retained here for the whole series, irrespective of the proportion of boric acid.

(ii) Those preparations in which mono-, di-, or tri-molecular proportions of boric acid are combined, with the aid of strong heat, with monomolecular proportions of glycerine, the resulting compounds being dissolved in glycerine. Recent experimental work on this group has been confined to the di-boric preparation, with or without dilution with alcohol.

The glycerine—boric acid compounds present in the dressings have not all been identified. The glyceroboric acid preparations, however, contain both boric acid and glyceroboric acid, a simple acid ester, in true solution in glycerine, while the mono- and di-boric dressings, in the preparation of which there is considerable heating, contain, besides boric acid and glyceroboric acid, other more complex esters. In the preparation of these complex esters, the water which is formed is driven off as steam, carrying with it a small amount of boric acid. There is consequently some loss of materials in producing the dressings. In the preparations, as set out on page 161 of our earlier paper, the loss of weight is:—

	Per cent.
Glyceroboric acid	0
Mono-boric preparation	9
Di-boric preparation	11

It was found that different amounts of boric acid would remain in stable solution in the different preparations. Thus, without strong heating, the most concentrated stable preparation that could be obtained

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contained the equivalent of 19.8 per cent. of boric acid in pure glycerine, whereas the di-boric preparation contained the equivalent of 26 per cent. boric acid.

Both glycerine and boric acid are soluble in alcohol, and stable glyceroboric acid preparations were obtained by adding definite amounts of alcohol to certain supersaturated solutions of boric acid in glycerine. In these, the percentage of boric acid approximated to that of a saturated solution in pure glycerine, as shown by the following figures:—

Preparation No.	Original Percentage by Weight of H_3BO_3.	Percentage of Alcohol by Volume in Final Preparation.	Percentage by Weight of H_3BO_3 in Final Preparation.
	%	%	%
2	19·8	0	19·8
9	23·0	25	19·1
11	23·6	20	20·5

The diluted di-boric preparation, containing 25 per cent. by volume of alcohol and the equivalent of 21.5 per cent. by weight of boric acid in the final preparation, was quite stable. The addition of denaturants in quantities required for excise purposes does not influence solubility, but affects the dressings in other ways which will be described in a later section.

The addition of water to glycerine greatly reduces its capacity to dissolve boric acid. Thus, only about half as much boric acid could be dissolved in 86.5 per cent. glycerine as in a similar volume of 99.5 per cent. glycerine. This probably accounts for the fact that preparations made from soap crude glycerine, which contains 80 per cent. glycerine, 7 to 8 per cent. water, 12 per cent. salt, and 1 per cent. organic impurities, almost invariably deposited boric acid on standing. This is one reason why these preparations were usually unsatisfactory.

From the therapeutic point of view, the most important chemical characteristics of the pure undiluted dressings are, firstly, that most glycerine–boric acid compounds are easily hydrolysed by water, and, secondly, that the addition of water to glycerine greatly reduces its capacity for dissolving boric acid. When applied to the struck area, the dressings penetrate the fleece to the skin, carrying boric acid in solution throughout the dressed areas. As struck areas are always wet with serous exudate, the dressings become mixed with water, hydrolyse, and boric acid is deposited in minute particles on the fleece, skin, and wounded surface. Should the treated area be exposed to rain, further deposition occurs. Because the boric acid is deposited in intimate association with the fleece and skin, and because it is not very soluble in water, it persists on the dressed area for a long time. Thus, a struck area on one sheep, which was dressed without removing the fleece and was subsequently exposed to weather and to several experimental washings, was found to contain boric acid over three months later.

It is this persistent deposit of boric acid that reduces liability to re-strike, and it was therefore important to determine whether the various modified dressings would hydrolyse and deposit boric acid readily. It was found that all the alcohol-diluted preparations, with the exception of the mono-boric preparation, deposited boric acid as rapidly on the addition of water as the undiluted preparations under similar conditions.

3. Examination of the Dressings.

Our methods of testing the dressings were described in the earlier paper. Since then, we have used the various glycerine—boric acid preparations on 208 strikes, using 10 strikes treated with other dressings for comparison. Details of the strikes and the dressings used during the second period are shown in Table 1. Thus, we have, since March, 1935, tested these dressings on a total of 333 strikes, using 28 strikes treated by other methods as controls.

TABLE 1.—STRIKES TREATED.

Dressing.	Artificial Body Strikes.	Natural Body Strikes.	Natural Crutch Strikes.	Artificial Re-strikes.	Total.
Pure glyceroboric acid diluted with alcohol	36	..	16	6	58
Crude glyceroboric acid diluted with alcohol	39	1	30	1	71
Mono-boric preparations ..	8	..	..	..	8
Pure di-boric preparations	6	..	..	1	7
Pure di-boric preparations diluted with alcohol	13	1	13	16	43
Crude di-boric preparations	7	..	..	..	7
Crude di-boric preparations diluted with alcohol	12	..	..	2	14
Other treatments for comparison	8	..	..	2	10
	129	2	59	28	218

As the glyceroboric acid dressings are easiest to prepare, and there is no loss in preparation, most attention was paid to them. They were used with and without alcohol, and the percentage by weight of boric acid was varied from 15 per cent. to 20.5 per cent. Most of the preparations made from crude glycerine, for which tests are listed, proved to be unstable on keeping.

4. Results of Recent Work.

The effects of the dressings on the sheep and on the maggots may be epitomized briefly as follows:—

(A) Of the preparations made with pure glycerine, the di-boric dressing has continued to give the best results, killing the maggots distinctly more quickly than the other preparations, and apparently having a slightly more beneficial effect on the wounds.

(B) Preparations made from soap crude glycerine were less efficient. The larvicidal effect was unsatisfactory, maggots in several instances surviving for more than 24 hours, and in one case continuing to work on the skin after dressing. Also, the strike wounds sometimes healed less rapidly and less cleanly than similar wounds treated with the pure preparations.

(C) Dilution with appropriate amounts of absolute ethyl alcohol decidedly improves all the dressings, whether made from pure or crude glycerine.

Neither alcohol nor alcohol mixed with glycerine in various proportions has any deleterious effect on normal skin, so, in order to find the most satisfactory dilution, dressings made up with various proportions of alcohol were used on strike wounds. It was found that no reaction followed the use of dressings containing 25 per cent. by volume or less of alcohol, but that 33 per cent. alcohol caused mild swelling, and 50 per cent. caused distinct and immediate swelling with congestion of the wound, which did not reduce for some time.

Dressings diluted with up to 25 per cent. of alcohol possess several advantages:—

1. Consistency and penetrating qualities of the dressings are greatly improved, with a consequent improvement in the ease with which a strike can be treated efficiently.

2. They irritate the maggots, and cause them to leave the strike more quickly than the undiluted dressings. Most die later from boric acid poisoning. For example, a sheep with a three-day old strike was dressed, and the maggots that dropped off were collected from the floor 1½ and 5 hours later. Of those collected after 1½ hours, 100 were placed on liver, on which they commenced to feed, but all died without pupating; 200 were placed on dry sand, into which they burrowed, and a few pupated, 6 flies emerging. Numerous maggots collected 5 hours after dropping off the strike were placed in dry sand, but no flies emerged.

3. They have a greater cleansing action on the strike wounds than the undiluted dressings. This is particularly noticeable with body strikes, which, after treatment with diluted dressing, present a remarkably fresh, washed, healthy appearance.

4. The wounds dry more quickly after treatment with them: the scabs are, if anything, cleaner and thinner, and lift away from the skin earlier than those formed after treatment with undiluted dressings. Healing is thus more rapid.

5. The improvement on adding alcohol is equally as marked with the preparations made from crude glycerine as with those made from pure glycerine, the end result being that the pure di-boric preparation diluted with alcohol is superior to all the other preparations, while the diluted crude di-boric preparation approaches the efficiency of the undiluted pure preparation.

6. The cost of the dressing is reduced by adding alcohol.

(D) The price of pure alcohol is prohibitive because of excise duty, and consideration was consequently given to the various denaturating agents that might be used. Methyl alcohol (methanol) up to 5 per cent. is quite satisfactory, and alcohol denatured in this way is obtainable under bond for manufacturing purposes, but it cannot be bought in the open market. Dressings diluted with 25 per cent. by volume ordinary commercial methylated spirit, unfortunately, did not prove satisfactory. Strike wounds dressed with these preparations showed considerable swelling, which persisted for several days, and the temperature of the sheep returned to normal more slowly than after the use of dressings diluted with pure alcohol. None of the denaturants, when used in the strength in which they are present in methylated spirit, has any detectable effect on the normal skin, but undiluted pyridine and benzene are intensely irritating, and we suspect that these may be the cause of the bad effect on the wounds. The present position is that the grower who wishes to use the dressing would be well advised to obtain it from a firm which can use the methanol-diluted alcohol, or, if he particularly desires to make his own preparation, to use not more than one part of methylated spirit to five of the dressing, instead of one part to three as with the pure spirit. Even this lower proportion of alcohol may not prove to be completely satisfactory in all cases.

(E) Sepsis has continued to be a minor source of trouble, interfering with prompt healing in about 16 per cent. of cases, chiefly in sheep under one year old. It was usually restricted to a small area in the centre of the strike, where maggot invasion had been deepest. The skin frequently healed over the infected subcutaneous tissue, forming a pus pocket. Some fluctuation and redness of the skin was generally evident, and thick creamy pus could be squeezed out. These pockets may persist for many weeks. Smears from the pus, on microscopical examination, always showed a mixed infection, small diphtheriods predominating, but cultures were always overgrown with an organism resembling *Bacillus proteus*. The occurrence of sepsis did not bear any relation to the dressing used nor to the severity of the strike. Some very severe foul strikes healed quickly without sepsis, while other relatively mild strikes became septic. Final healing often left persistent evidence of redundant granulation in the form of patchy thickenings in the skin, and sometimes projecting, papillate tags.

Acriflavine, 1 in 1,000, was incorporated in the dressing in an attempt to combat the sepsis, but was ineffective. Other antiseptics are now being considered.

5. Studies of Re-Strike.

The method we have used for testing resistance to re-strike is similar to that described in our earlier paper for producing initial strikes, that is to say the area is thoroughly wetted and approximately 2,000 newly

hatched maggots are washed on to it. As the fleece was sometimes so short on the treated area that it was considered doubtful whether the maggots would find adequate protection, a wet cotton wool pad protected on the outside by a layer of cellophane, was sometimes used to shelter the maggots and prevent evaporation. Experience has shown that this is the most rigorous test to which the area can be subjected. Treated areas were subjected to numerous attempts at re-strike, until a positive result was obtained, the sheep usually being turned out into the paddock between attempts. Thus, to take an extreme example, sheep No. 65 was subjected to ten attempts at re-strike between the 5th and 103rd day after the original strike was dressed with the mono-boric preparation before a re-strike was produced.

This type of test does not pretend to meet all the conditions that would occur in the field, but we consider it is reliable with these particular dressings, for we have shown that they have no repellent qualities, but depend for their effect on the boric acid killing the newly hatched maggots.

Using this method, we have made 141 attempts to produce re-strikes on areas which had been dressed with the various glycerine—boric acid preparations, the results being set out in Table 2. It will be seen that,

TABLE 2.—RE-STRIKE EXPERIMENTS (BODY STRIKES).

Dressing.	1st to 3rd Week Inclusive.		4th to 6th Week Inclusive.		7th to 9th Week Inclusive.		10th to 15th Week Inclusive.		Total.		Day of First Re-strike.
	+	—	+	—	+	—	+	—	+	—	
Pure preparations ..	0	17	1	5	0	1	4	8	5	31	36
Pure preparations diluted with alcohol	0	8	6	15	2	3	..		8	26	29
Crude preparations ..	..		0	5	5	9	2	4	8	18	50*
Crude preparations diluted with alcohol	0	4	5	25	2	10	..		7	39	22
Total	0	29	12	50	9	23	6	12	27	114	
Percentage protection	100		81		72		67		..		
No dressing	2	0	1	0	..		..		3	0	
Other treatments ..	4	0	..		..		..		4	0	

+ Re-strikes produced. — Re-strikes failed.

* Tests in earlier periods too few for this figure to be significant.

taking the dressings as a whole, we obtained quite a fair degree of protection from re-strike, and it must be remembered that the protection was definite, for the strikes would certainly have developed if the dressing had not been present.

Re-strikes were never obtained before the fourth week on areas dressed with glycerine—boric acid preparations. They were then mild and limited in extent; frequently no more than 20 maggots survived to produce a slight invasion of the skin, but they failed to reach maturity. In the sixth week, the type of re-strike varied but was usually moderately severe. After the sixth week, re-strike resembled a strike of average severity, involving about 15 square inches with irregular extensions and marked swelling and invasion of the skin. There was no relation between the severity of the original strike or the dressing used and the extent and severity of the re-strike. The undiluted preparations on the whole gave better protection than those diluted with alcohol.

6. Prophylactic Use of the Dressings.

The re-strike experiments throw some light on the possible prophylactic value of the dressings, but, in order to test this point more fully, several sheep were taken and the preparations were rubbed into the normal unstuck fleece of the back. They were then turned out into the paddock, and were subsequently brought into the insectary at various periods for attempts to produce strikes on the treated areas. At each attempt, the area was thoroughly saturated with water and 2,000 maggots were washed on to the skin. The results were:—

Pure glyceroboric acid preparation containing 50 *per cent. alcohol.*

Four attempts to produce strike from the 36th to the 50th day after treatment; none successful.

Crude mono-boric preparation containing 50 *per cent. alcohol.*

Nine attempts to produce strike from the 19th to the 57th day; none successful.

Pure di-boric preparation containing 25 *per cent. alcohol.*

1. Six attempts to produce strike from the 35th to the 81st day; at the attempt on the 70th day, a minute strike developed, but the maggots failed to survive, no additional dressing being used; at the attempt on the 81st day, a superficial strike 1 inch in diameter developed, and sixteen maggots survived.
2. Six attempts to produce strike from the 35th to the 81st day; none successful.
3. Four attempts to produce strike from the 63rd to the 81st day; none successful.
4. Four attempts to produce strike from the 63rd to the 81st day; none successful.

Controls.

As controls, three clean areas were treated with other dressings. Strikes were obtained on them at the first attempt in each case. The time interval was thirteen to eighteen days. Strikes can always be produced on untreated areas.

It is significant, we think, that these sheep were exposed not only to ordinary rains and dews but to several thorough washings as well, and that one of the preparations was made with crude glycerine, while two contained 50 per cent. of alcohol. Thus, there is reason to expect that the dressings may prove useful as preventive applications on rams and stud ewes. The di-boric preparation diluted with alcohol, when placed on the heads of rams, penetrates the wool well, sweetens the area at the base of the horns, and softens the brittle, calloused skin on the back of the head.

7. Conclusions.

1. The additional evidence obtained supports the view that the di-boric preparation has valuable properties as a dressing for fly-struck sheep, both by reason of its immediate effects on the maggots, on the well-being of the sheep, and on the strike wounds, and of its later effects in preventing re-strike.

2. The preparation is decidely improved by the addition of not more than 25 per cent. by volume of ethyl alcohol, which may be denatured with methanol.

3. Soap crude glycerine is not a satisfactory substitute for pure glycerine in the preparation of the dressings.

4. The preparations may prove useful as preventives, more particularly on the heads of rams.

The Influence of Rainfall on the Yield of a Natural Pasture.

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Summary.

The influence of annual, half-yearly, tri-monthly, bi-monthly, and monthly rainfall on the yield of unfertilized and top-dressed natural pasture, for a period of ten seasons at the Waite Institute, has been investigated by correlation and regression.

High significant positive correlations were obtained between the yield of each pasture and the rainfall for January-December, January-June, the tri-monthly and bi-monthly periods between February and July, and the single month of April. The correlation was strongest in the period April to June inclusive, which coincides with the early stages of seasonal growth.

High significant negative correlations were found between the yield of each pasture and November rainfall. There was, however, a significant negative relationship, for the ten years in question, between April-June rainfall and November rainfall. Elimination of this effect by partial correlation reduced the association between November rainfall and yield to insignificance.

The effectiveness of autumnal and early winter rainfall and the relative ineffectiveness of late winter and spring rainfall in determining yield appear to be associated with the type of pasture investigated, which is composed of species with a restricted growing period and a limited capacity for production.

The replacement of these species by cultivated herbage plants with a perennial deep-rooted habit and a capacity for growth over all or most of the year enables the rainfall to be used more effectively, and constitutes an important application of the results in practice.

1. Introduction.

Among the numerous factors which influence agricultural production, rainfall is largely the major determinant of yield, especially where the reliability of effective rains is not high. The amount of annual rainfall, however, is not usually so important as the quantities falling at critical periods of crop and pasture growth. Unfortunately, there is a paucity of data concerning the question under Australian conditions. Despite this, however, the concept of an "ideal" type of rainfall for given requirements is generally admitted. Apart from rain *per se,* the associated atmospheric factors of temperature, humidity, and wind velocity, by governing the rate at which moisture is dissipated through evaporation and transpiration, influence the effectiveness of rainfall to a marked degree.

The influence of weather on crop yields has received detailed attention in England, (3), (4), (5), (7), and much work on this aspect has been carried out in other countries.

In Australia, the problem has been studied to a limited extent, chiefly by Barkley, who concluded (1) that the rain falling immediately prior to the flowering of the wheat plant—that is, the rainfall for August

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and September, in northern Victoria—exercised a powerful influence on the resulting harvest. The work of Richardson (6) on the water requirements of farm crops under Victorian conditions stressed the value of September-October rains in increasing wheat yield; it was shown that maximum losses of water by transpiration occurred at that particular time of the year. Apart from moisture actually gained from rain falling at, or immediately before, flowering, however, soil and subsoil reserves of moisture accumulated previously must play a substantial part in supplying water during the spring period, and furthermore, the conservation of soil moisture by lessened transpiration following increased humidity and lowered temperature is probably an important associated effect of rainfall.

In connexion with pastoral production, Barkley (2) also investigated the influence of seasonal rainfall on the yearly wool clip of a station situated in the Western District of Victoria, and concluded that the major influence of rainfall in this case was restricted to the two-month period January and February, eight months prior to shearing early in November.

The effect of seasonal rainfall on pasture yields appears to have been little investigated. Few instances are available in which yields of pasture grass or herbage have been taken over a sufficient period to enable statistical treatment to be applied.

2. Scope of Investigation.

In the present case, advantage has been taken of a ten years' sequence of yields from plots established on an area of natural pasture at the Waite Institute in 1925. This area is typical of much grazing land in the better rainfall country of South Australia, and is dominated in its unfertilized condition by *Danthonia,* with smaller quantities of exotic annuals such as *Festuca myuros, Trifolium arvense, T. procumbens, Erodium botrys,* and *Echium plantagineum.* Under top-dressing with superphosphate, the pasture has become dominated by these annuals, with considerable reduction in the amount of *Danthonia* present.

The yields of pasture were taken from two plots of 0.8 acre each, one unfertilized and the other top-dressed with superphosphate (40 lb. P_2O_5) for a period of ten consecutive seasons at the Waite Institute. The plots were grazed by sheep, and the yields obtained by sampling from eight randomized quadrats of $2\frac{1}{2}$ square metres each per plot; the quadrat frames were removed to grazed pasture at the commencement of each season. The rainfall figures are those taken from the Waite Institute rain gauge, situated approximately 10 chains from the plots.

3. Experimental Data.

The yields of natural pasture from the unfertilized and the top-dressed plots, together with the monthly rainfall for each of the years 1925-1934, are given in Table 1. The pasture yields are shown graphically in conjunction with tri-monthly rainfall for the periods January-March, April-June, July-September, and October-December, in Fig. 1.

TABLE 1.—SHOWING YIELDS OF NATURAL PASTURE AND MONTHLY RAINFALL FOR EACH OF THE SEASONS 1925-34, WAITE INSTITUTE.

——	1925.	1926.	1927.	1928.	1929.	1930.	1931.	1932.	1933.	1934.	Mean.	Standard. Error
1. Yield of Natural Pasture (cwt. per acre)—												
(*a*) Unfertilized ..	21·76	28·35	18·00	24·31	17·69	20·67	41·43	56·92	51·43	20·23	**30·08**	±4·22
(*b*) Top dressed with superphosphate	27·74	43·20	28·54	39·63	33·70	30·32	47·50	75·66	64·70	38·00	**42·90**	±4·37
(*c*) Increase ..	5·98	14·85	10·54	15·32	16·01	9·65	6·07	18·74	13·27	17·77	**12·82**	±1·44
						Monthly Total.						
2. Rainfall (inches)—												
January ..	0·57	..	0·24	1·09	0·67	0·03	0·76	0·23	1·22	0·58	**0·54**	
February ..	3·16	1·08	1·09	2·63	0·03	0·36	0·27	1·60	0·40	0·14	**1·08**	
March	0·37	0·01	1·15	1·37	0·25	0·05	1·72	1·64	1·42	0·72	**0·87**	
April	1·16	1·83	0·42	1·36	0·65	1·02	1·06	5·51	2·09	1·48	**1·66**	
May	5·11	6·27	3·31	2·65	1·73	0·97	3·25	2·11	6·85	0·06	**3·23**	
June	2·20	2·14	2·53	4·58	4·26	1·52	5·97	5·27	1·80	1·14	**3·14**	
July	3·14	2·29	3·51	3·33	2·65	4·90	4·17	3·53	2·19	1·18	**3·09**	
August	1·84	4·71	4·12	0·84	2·37	3·73	3·26	3·61	3·85	4·90	**3·32**	
September ..	3·76	2·76	1·17	2·04	2·72	3·21	4·51	1·94	3·71	4·05	**2·99**	
October ..	1·19	1·91	0·41	2·97	1·17	3·35	0·63	2·43	0·68	2·50	**1·72**	
November ..	0·47	0·79	1·42	0·53	1·26	1·12	1·07	0·56	0·26	3·79	**1·13**	
December ..	0·14	1·97	1·62	0·15	3·68	0·92	0·21	0·40	0·42	1·53	**1·10**	
Total ..	23·12	25·77	21·00	23·54	21·44	21·18	26·90	28·83	24·90	22·07	**23·88**	

(i) *Statistical method.*

The comparatively short sequence of seasons available precludes a detailed analysis according to the methods developed by Fisher for investigating the influence of rainfall on the yield of wheat, and which were subsequently used in similar investigations with barley and mangolds.

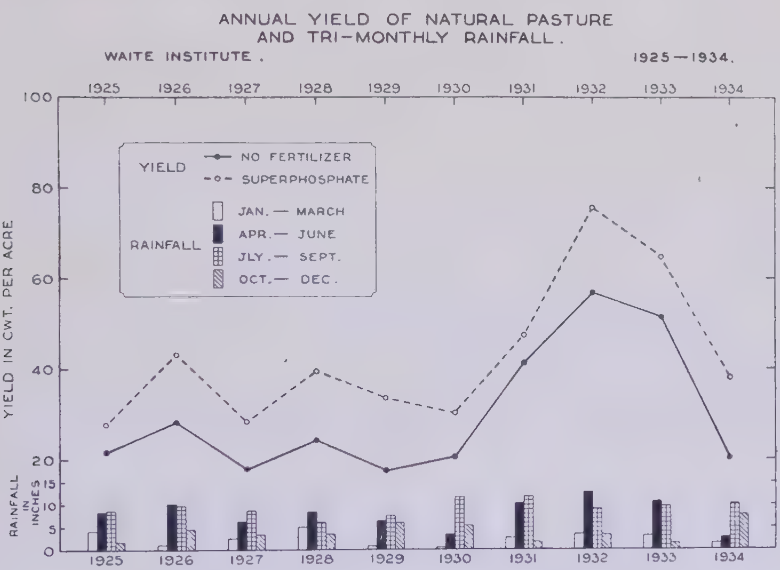

FIG. 1.—Graph showing the annual yield of natural pasture at the Waite Institute, 1925–34, (*a*) unfertilized, (*b*) top-dressed with 185 lb. superphosphate per acre, together with the rainfall in quarterly periods for each year.

A preliminary examination was commenced prior to the completion of the tenth season's harvest, and, in view of the marked increases in yield during the seventh, eighth, and ninth seasons, it was deemed advisable to take account of the yield trend by fitting a curve of the first degree and similarly treating the rainfall figures before correlating the variables. The inclusion of the tenth year considerably reduced the regression of yield on time, but the co-efficient, though insignificant, still remained sufficiently large to reduce the standard error of the mean yield; for this reason it was retained.

The yield residuals were correlated with the rainfall residuals of the following periods:—(i) annual, (ii) half-yearly, (iii) tri-monthly, (iv) bi-monthly, (v) monthly.

(ii) *Results of analysis by correlation and regression.*

The correlation coefficients for the yield of pasture and the annual, half-yearly, quarterly, bi-monthly, and monthly rainfall are given in Table 2. For brevity, only values greater than + 0.49 and less than — 0.49 have been included.

TABLE 2.—RAINFALL PERIOD.

Annual.	Half-yearly.	Quarterly.	Bi-monthly.	Monthly.
(a) No fertilizer.				
		Feb.-Apl. + 0·73‡	Feb.-Mar. + 0·53	March + 0·57
		Mar.-May + 0·93*	Mar.-Apl. + 0·82*	April + 0·73‡
	Jan.-June + 0·91*	Apl.-June + 0·96*	Apl.-May + 0·89*	May + 0·67‡
Jan.-Dec. + 0·90*		May-July + 0·85*	May-June + 0·85*	Nov. − 0·81*
	July-Dec. − 0·62	Sept.-Nov. − 0·63	Oct.-Nov. − 0·68‡	Dec. − 0·50
		Oct.-Dec. − 0·78†	Nov.-Dec. − 0·76†	
(b) Superphosphate.				
		Feb.-Apl. + 0·78†	Feb.-Mar. + 0·50	March + 0·50
		Mar.-May + 0·91*	Mar.-Apl. + 0·89*	April + 0·84*
	Jan. June + 0·89*	Apl.-June + 0·95*	Apl.-May + 0·88*	May + 0·59
Jan. Dec. + 0·88*		May-July + 0·72‡	May-June + 0·78†	Nov. − 0·74‡
	July Dec. − 0·60	Sept.-Nov. − 0·62	Oct.-Nov. − 0·54	
		Oct.-Dec. − 0·58	Nov.-Dec. − 0·61	

Significance of the correlation coefficient.

* P < 0·01.   † P < 0·02.   ‡ P < 0·05.

In Table 3, the complete series of monthly and bi-monthly values for the correlation coefficient (r) and the regression coefficient (b) in cwts. per acre per inch of rain are given. The seasonal trend of the correlation coefficient for monthly and bi-monthly periods of rainfall is shown graphically in Figs. 2 and 3 respectively.

The values for the correlation coefficient given in Tables 2 and 3 indicate a relatively high degree of association between yield and rain falling within the March to June period; with the relationship strongest in the month of April. From June to August, the correlation coefficient falls towards zero, and from August onwards becomes negative, reaching a high and significant negative value in the month of November. From November to April, there is a continuous change in the reverse direction, zero being approached again in January. The bi-monthly values show a similar seasonal trend, but the positive figures for March-April and April-May are both higher than for the single

TABLE 3.

(i) *Monthly Intervals.*

—	Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
						1. *No Fertilizer.*						
r ..	+0·09	+0·38	+ 0·57	+0·73‡	+0·67‡	+0·45	+0·19	−0·06	−0·08	−0·25	− 0·81*	−0·50
b ..	+2·97	+5·49	+12·09	+6·90‡	+4·06‡	+3·26	+2·36	−0·60	−0·97	−3·00	−11·17*	−5·64
						2. *Superphosphate.*						
r ..	+0·04	+0·39	+ 0·50	+0·84*	+0·59	+0·43	+0·02	−0·04	−0·28	−0·11	−0·74‡	−0·34
b ..	+1·46	+5·98	+10·88	+8·25*	+3·74	+3·26	+0·29	−0·42	−3·60	−1·41	−10·55‡	−3·92

(ii) *Bi-monthly Intervals.*

—	Dec.-Jan.	Jan.-Feb.	Feb.-Mar.	Mar.-Apl.	Apl.-May.	May-June.	June-July.	July-Aug.	Aug.-Sept.	Sept.-Oct.	Oct.-Nov.	Nov.-Dec.
						1. *No Fertilizer.*						
r ..	−0 34	+0·34	+0·53	+0·82*	+0·89*	+0·85*	+0·41	+0·10	−0·09	−0·26	−0·68‡	−0·76†
b ..	−3·84	+3·98	+5·24	+6·43*	+4·19*	+4·27*	+2·22	+0·89	−0·79	−2·46	−5·85‡	−5·48†
						2. *Superphosphate.*						
r ..	−0·46	+0·33	+0·50	+0·89*	+0·88*	+0·78†	+0·33	−0·02	−0·21	−0·29	−0·54	−0·61
b ..	−5·36	+4·08	+5·20	+7·20*	+4·33*	+4·06†	+1·82	−0·15	−1·79	−2·95	−4·81	−4·59

Significance of correlation or regression.
* $P < 0{\cdot}01$. † $P < 0{\cdot}02$. ‡ $P < 0{\cdot}05$.

month of April, whereas the negative figures for October-November and November-December are both lower than for the single month of November.

While the highest positive correlation coefficients for monthly rainfall occur in April, the regression coefficients reach their highest positive values in March, indicating that March rainfall is more effective in increasing the yield of pasture than rain falling in any other month. The March values for each treatment, however, do not differ significantly from zero. Negative regression, as in the case of negative correlation, is highest in November.

The points of special interest arising from the data given in Tables 2 and 3 are, firstly, the apparent dependence of the pasture yield under these conditions on autumnal rainfall; secondly, the absence of relationship between yield and the amount of rain falling between July and October; and, finally, significant negative values for correlation between yield and rain falling in November or in the October-December period.

The effectiveness of autumn rainfall and the comparative ineffectiveness of winter rainfall in determining yield are dealt with in the discussion (q.v.). Due consideration of the pasture species concerned, in relation to varying factors of their environment, indicates that the values obtained for the period March to September at least are cogent, and have an important practical bearing in connexion with the replacement of natural grassland by seeded pastures.

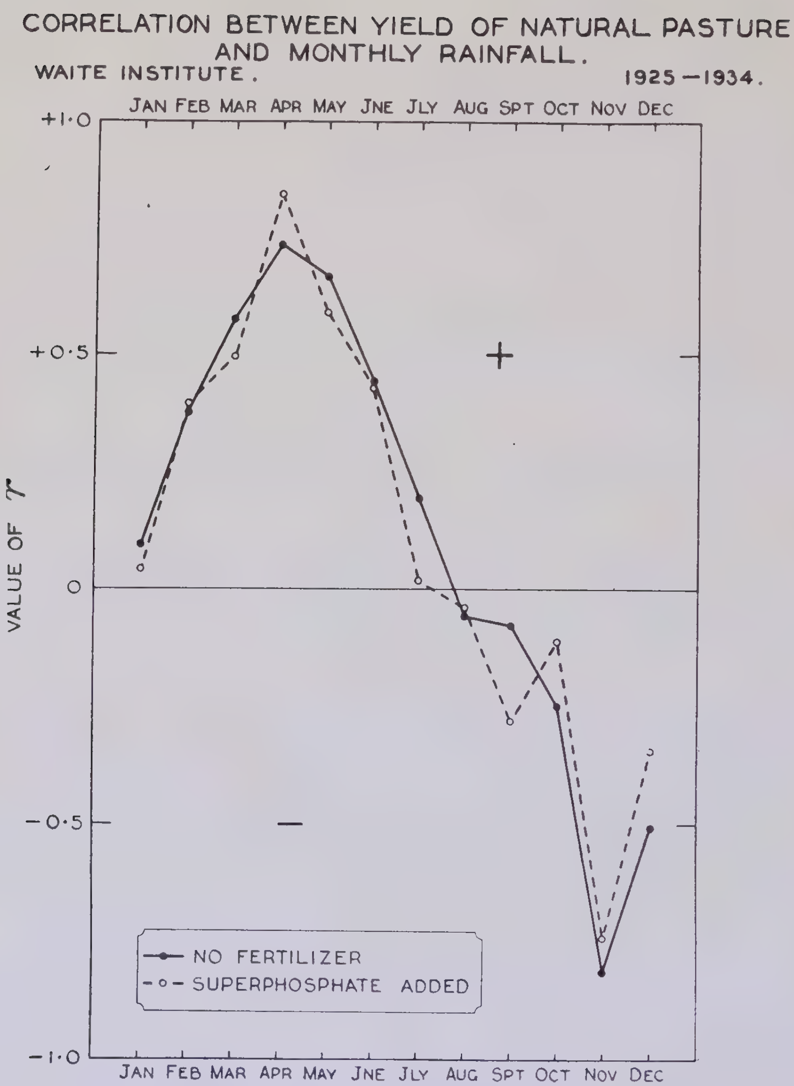

Fig. 2.—Graph showing correlation coefficient (r) for the annual yield of natural pasture, (a) unfertilized, (b) top-dressed with superphosphate, and the rainfall for each month, Waite Institute, 1925–34.

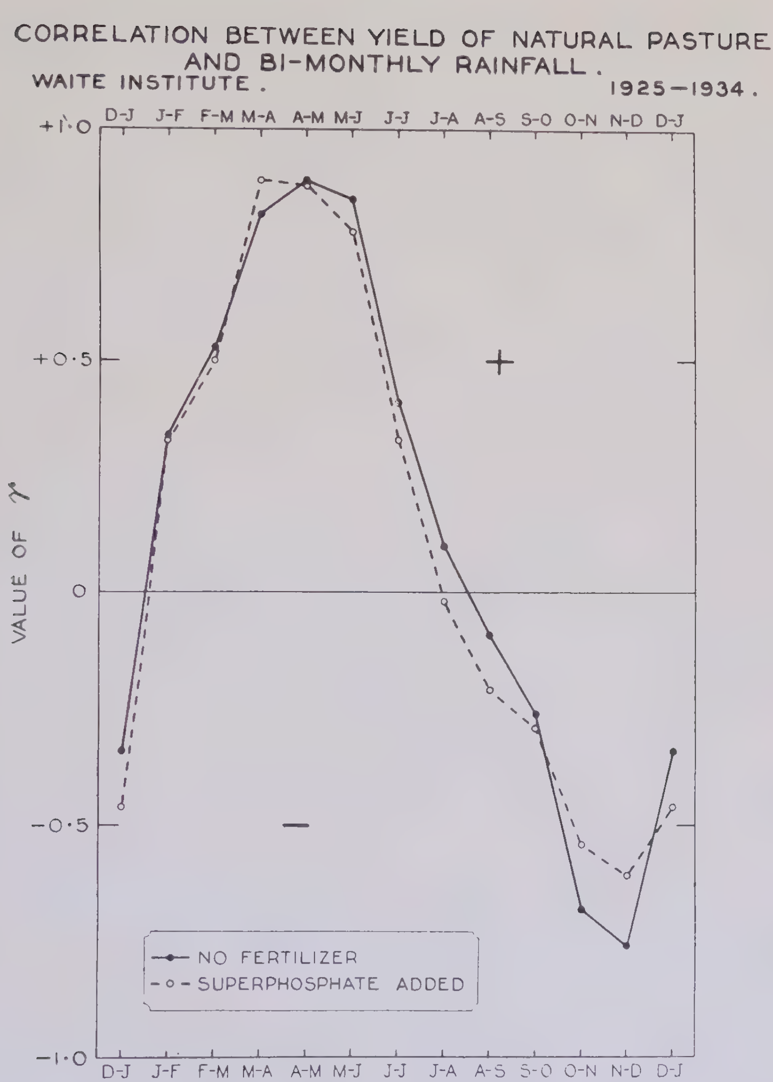

FIG. 3.—Graph showing correlation coefficient (r) for the annual yield of natural pasture, (a) unfertilized, (b) top-dressed with superphosphate, and the rainfall in bi-monthly periods, Waite Institute, 1925–34.

The high negative correlation between yield and November rainfall is not by itself acceptable, however, because in each season the harvesting of the pasture samples was completed early in November, growth normally ceasing at this time. It is manifestly unlikely that rain falling at or after harvest could significantly affect the total yield of pasture in either an adverse or beneficial manner. It is reasonable, therefore, to suppose that a large proportion of the apparent negative association between yield and November rain may be due to the fact that November rainfall is negatively correlated with rain in other parts of the season. This actually proved to be the case, as will be seen from Table 4, wherein are given the values of the correlation between yield and spring-early summer rainfall after allowance has been made for April-June rainfall.

Table 4.—Partial Correlation Coefficients (April–June Rainfall Eliminated).

(a) Monthly Intervals.

—	Aug.	Sept.	Oct.	Nov.	Dec.
Nil	+0·36	+0·05	+0·14	−0·43	−0·54
Super. ..	+0·37	−0·60	+0·60	−0·05	+0·10

(b) Bi-monthly Intervals.

—	Oct.-Nov.	Nov.-Dec.
Nil	−0·10	−0·62

* None of the above values is significant.

On removing the correlation between April-June rainfall and August-September, &c., rainfall, the value of r for yield correlated with rainfall for the months following July becomes irregular and in all cases insignificant.

The correlation coefficient for April-June rainfall with November rainfall is –0.77 and is significant at the 2 per cent. point. Allowing for this relation, the value of r for yield with November rainfall becomes reduced from –0.81 (significant at the 1 per cent. point) to –0.43 (insignificant) in the case of the unfertilized pasture and from -0.74 (significant at the 5 per cent. point) to –0.05 (insignificant) with phosphated pasture.

Thus, for the period of ten seasons under review, there appears to be a significant negative relationship between November rainfall and April-June rainfall, and the recorded negative correlations between yield and November rainfall are probably not due to any influence of November rainfall on yield.

4. Discussion.

It seems apparent that the total seasonal yield of natural pasture at the Waite Institute over the period 1925-34 has been largely determined by the amount of rain received during March, April, May, and June. Furthermore, rain falling after June or July appears to have had little significant influence on the total pasture yield, despite the fact that growth each year proceeded until November. In the event of negligible rain prior to July, succeeding rains would, of course, be important, but a low final yield would be expected.

The importance of autumnal rains in a winter rainfall environment may be accounted for by the fact that at this time of the year soil temperatures are rapidly falling to values which in June, July, and August render the germination and vegetative growth of herbage plants particularly slow. At the Waite Institute, the mean monthly soil temperature at a depth of 1 inch is approximately 70° F. in April, compared with 55° F. in June, July, and August, with a mean monthly minimum value of 46.4° F. in July. The increased length of day in early autumn, compared with late autumn and winter, may also be important.

It is obvious, then, that given suitable soil conditions, rain falling in early autumn will tend to produce considerably more growth than similar quantities received in late autumn or winter, provided rainfall suitably exceeds evaporation for a sufficient interval of time. In the case of the ten seasons under review, April-June rainfall exceeded April-June evaporation in the four years giving the four highest yields. In each of the four years with the four lowest yields there was a deficiency of more than 3 inches for this period. The remaining two yields were also on the low side. In one case (1928), there was a deficiency of 1.57 inches; in the other (1925), rainfall exceeded evaporation by 0.49 inches over April-June, with a deficiency, however, of 0.21 inches over April-May.

The major influences of this early development on ultimate production are at least threefold. Firstly, there is the direct effect on growth, which in the early stages is greatly dependent on previous accumulation. Secondly, the earlier the commencement of growth the longer the interval of time over which growth can proceed, as the end point with these species has been remarkably constant, depending for the most part on the more or less constant length of day factor. Finally, early development of the root system becomes important in winter when the increased depth of penetration attained secures the advantages of warmer soil and greater capacity both for root respiration and the picking up of partially leached nitrates.

The fact that growth and transpiration accelerate from July onwards, reaching a maximum in September and October, tends to suggest that spring rains also should be highly effective in determining the ultimate pasture yield. The absence of relationship between yield and rain falling after the end of June, therefore, may at first sight seem difficult to comprehend, and was at least unexpected.

A consideration of the particular species concerned, however, provides an explanation for the relative ineffectiveness of late winter and spring rains compared with autumnal rains. These species are adapted to exigent soil conditions and to a comparatively short rainy period; their potentialities for increased production are not high.

It is of interest to note that the mean rainfall for the April-June period, over this sequence of ten years, is 8.03 inches. Transpiration experiments carried out at the Waite Institute during the same period suggest that the transpiration requirements of the mean yield from the higher yielding plot would be approximately this amount.

It would thus be seen that the ultimate development of the inherently early-maturing and short-lived species which comprise these natural pastures is largely predetermined by conditions during the March-June period, and that rains falling later, whilst by no means negligible, are by comparison much less important for this type of pasture, and in certain seasons may be quite ineffective.

The above results, whilst admittedly tentative, provide a new interpretation for differences in yield due to seasonal variation and also indicate an important application in practice. This is the establishment of herbage species with the combined capacities of drought-resistance and sustained vegetative growth, enabling full advantage to be taken of late winter and spring rains as well as rains falling earlier in the season. Two species which fulfil these requirements in particular are lucerne and *Phalaris tuberosa,* which, by virtue of their perennial deep-rooting habit, drought-resistance, and capacity for growth over all or most of the year, are able to utilize the rainfall to a maximum degree and frequently to provide green herbage at those times of the year when it is normally absent.

5. Acknowledgment.

We desire to thank Mr. C. A. N. Smith, B.Agr.Sc., for carrying out much of the arithmetical work involved in the calculation of the correlation and regression values.

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A Preliminary Report on Methods for the Preservation of Orange Juice.

*By L. J. Lynch, B.Sc.Agr.**

1. Definition.

It may be advisable at the outset to define the term "orange juice," as otherwise misconceptions may occur in the matter of difficulties relating to its preservation.

Orange juice, according to the "Definitions and Standards for Food Products," (7) is the unfermented juice obtained from sound, ripe, sweet, oranges. It may contain a portion of the pulp and/or of the volatile oil.

This definition clearly demarcates orange juice from carbonated and preserved beverages which frequently contain approximately 10 per cent. of pure juice. The preservation of these beverages for commercial distribution presents but little difficulty.

2. Quality of Product.

The ideal to be aimed at in the preservation of orange juice is a product which will open up after prolonged storage in a condition approximating to fresh juice with respect to taste, flavour, aroma, and colour. Preservation should be effected in such a way that nothing is added to, or taken away from, the fresh juice. The original juice should be of good flavour and aroma, rich in colour, sweet, and yet possessing a pleasing tartness. It should contain from 5 per cent. to 10 per cent. of juice cell pulp in order to convince the consumer of its genuineness. To obtain juice of the requisite standard, careful selection of fruit is a matter of prime importance. In the United States of America, experience has shown that Valencias produce the best juice, Navels being much inferior. Fruit is used which is culled by reason of size, skin defects of mechanical origin, or of shape. Diseased fruit is most definitely rejected.

According to McNair (10), orange juice in its most palatable condition contains eight parts of sugar to one of acid. The sugar/acid ratio of oranges varies with locality and cultural practice; hence it is necessary, once having adopted a standard ratio, to see that it is maintained. Standardization of taste, colour, and juice cell pulp content may be conveniently carried out commercially by blending the juice of fruit from a number of districts.

3. Defects of Preserved Orange Juice.

The degradation of orange juice during processes of preservation has been shown by Joslyn (8) to be due to three types of change—

(i) Change due to living organisms.
(ii) Change due to enzymic action.
(iii) Change due to oxidation and chemical reactions between various constituents of the juice.

* An officer of the Council engaged on the investigations of the storage of citrus fruit in which the Council is co-operating with the Departments of Agriculture of New South Wales, Victoria, and South Australia. (For details see this Journal **8**: 239, 1935.)

In addition to defects from these causes, juice may be of inferior quality, as a result either of defects inherent in the fruit itself, or of those which have been incorporated during the process of preservation.

(i) *Change Due to Living Organisms.*—Defects of this type are due to fermentative changes. The growth of moulds, yeasts, and bacteria may be inhibited by the addition of preservatives, but many of these are prohibited, and in any case such addition transgresses the rule that "nothing should be added to nor extracted from the original juice."

A sterile product may be obtained by pasteurization, and this is the general commercial practice. Batch pasteurization is ruled out by reason of the fact that prolonged holding and localized heating impart a "cooked" flavour to the juice. Moreover, such heating tends to accelerate oxidative changes in the product. The latter objection applies to flash pasteurization under normal conditions, but Cruess (6), Mottern, and Loesecke (13), and other recent investigators are of the opinion that no degradation occurs during the flash pasteurization of de-aerated juice. Such juice may be pasteurized while subject to a vacuum of 25″ or more, or in the presence of carbon dioxide or nitrogen.

(ii) *Changes Due to Enzymes.*—These are of two main types—

(*a*) Changes due to oxidizing enzymes.

(*b*) Changes due to pectic enzymes.

Oxidations are probably a more serious cause of deterioration in orange juice than any other type of change.

Cruess (6) is of the opinion that browning or darkening of the juice on standing is due to oxidation of substances of the types of catechol-tannins, and while it may be in part non-enzymic, it is mostly due to the presence of an oxidase system. If this is so, it is probable that the oxidase must have been incorporated in the juice during extraction, since it is generally believed that while an incomplete oxidase is present in the flavedo and albedo of the orange no such system occurs in the juice itself. This point is important when considering the method of extraction of the juice, a matter which is discussed in a later section of the report.

Two other serious defects, viz., "bitter" and "turpentine" tastes, may be attributed also to oxidative change. Turpentine taste is due to the presence in the juice of terpenes, sequiterpenes, aldehydes, ketones, alcohols, and the like, which are easily oxidized. Toulouse (16) points out that terpenes contribute but little to the flavour of fresh juice, but when oxidized are productive of off-flavours which are intensely objectionable. Such terpenes do not occur naturally in the juice, but in the oil of the rind, where the chief of them, limonene, is present to the extent of 95 per cent. of the oil content. Again, it will be seen later that these defects may be eliminated by a suitable method of juice extraction.

Bitter taste or flavour has been the subject of an intensive investigation by Camp and Stahle, who have shown conclusively that the bitter principle is not inherent in the juice, but is resident in the carpel walls and albedo, from which it is removed by improper methods of extraction.

As a result of the activity of pectic enzymes, the dissolved pectins in the juice are clumped, and small quantities of gel float in the liquid, eventually settling to the bottom, from which they are easily disturbed by agitation. The effect is practically innocuous other than with regard to appearance, a factor of great commercial importance. A large number of chromatophores which normally float in the juice, and to which the colour is due, are incorporated during gel formation, and are removed from the liquid by subsidence.

Morris (11, 12) considers that gelation may be largely overcome by picking the fruit at a time when the pectin content of the juice is at a minimum, consistent always with ripeness. It is considered, however, that the time of picking of the fruit should not be compromised by a factor such as this, since the quality of the final product depends absolutely upon the quality of the original juice.

Joslyn and Marsh (9) have investigated "cloudiness" in preserved orange juice, and indicate that pectic enzymes are destroyed by heating juice for two minutes at 190° F., or for eight minutes at 185° F. Thus the defect may be remedied by pasteurization. This process is also effective in retarding, if not entirely inhibiting, the activity of oxidizing enzymes previously discussed.

(iii) *Changes Due to Oxidation and Chemical Reactions between Constituents of the Juice.*—Apart from enzymic oxidations, Cruess (5) has demonstrated that oxidations which are non-enzymic in nature occur in orange juice. The non-enzymic process is considerably slower than that due to enzyme action. Oxidations of the type now under discussion may readily be prevented by the addition of small amounts of anti-oxidants such as salts of sulphurous acid, &c., but here again such procedure infringes the "addition and subtraction" dictum. An interesting contribution from an anonymous source (1) in *Food Industries* points out that, at present, sulphur dioxide is in general use for the prevention of discolouration of dried fruits—an oxidative process—but that this may be substituted by pineapple juice, the natural activator, probably glutathione, of the proteolytic enzyme (bromelin) in this juice, being a sulphydryl compound. It would seem that pineapple juice may be utilized for the prevention of oxidative processes in orange juice, since, although it is certainly an addition to the original substance, yet it is a naturally occurring fruit juice in itself.

Apart from oxidations, chemical reactions of various types occur among the constituents of orange juice, but little is known either as to their nature or effect by reason of our imperfect knowledge of the minor constituents of citrus fruits generally. Limey or musty taste is thought to be due to chemical change as yet undetermined.

4. Commercial Procedure in the United States of America.

(i) *Selection of Fruit.*—It is essential that the fruit should be thoroughly ripe, as the use of immature material undoubtedly accentuates any bitterness which may occur. The use of diseased fruit must be avoided if a high class beverage is to be produced. Apart from these considerations, fruit should be so selected that the juice when suitably blended may conform with the standards heretofore laid down.

((ii) *Preparation of Fruit and Juice Extraction.*—After picking, the fruit must be cooled to 32° F. as soon as possible, and held at that temperature until expressed. The oranges should be well washed, preferably in a disinfectant solution, and finally rinsed several times in pure water.

Four methods of extraction are available, and these have been studied by Camp and Stahle (3). They are as follows:—

(*a*) The halved unpeeled fruit is extracted by means of a high-speed rotating burr. Pressure on the rind and rupture of the carpel walls and albedo incorporates air, oil, and bitter principle with the juice.

(*b*) The halved unpeeled fruit is extracted by compression. This introduces large quantities of oil, but no bitter principle, into the juice.

(*c*) Worm-type pressure on peeled fruit. Absence of rind eliminates oil in the juice, but the tearing of the tissues is responsible for the addition of bitter principle.

(*d*) The halved peeled fruit is extracted by compression. This is considered to be the only satisfactory method, since neither bitter principle nor oil are thereby incorporated.

A number of efficient types of automatic peeling machine, such as the Coons Vertical Peeler, have been placed on the market.

At this point, three important factors relating to the process in general should be stressed.

Metal contact with orange juice may result in serious deterioration, partly by its action as a catalyst, and partly by reason of its interaction with the organic acids of the juice. For this reason, it is recommended that, wherever juice and metal come into contact, the latter should be of stainless steel, aluminium, or citrus enamel lined (evidently an enamel used for containers of citrus juice in America; particulars of composition are not available).

Scrupulous cleanliness, both personal and with regard to apparatus, is absoluely essential.

Orange juice is particularly prone to the adsorption of flavours, and it is, necessary, in consequence, that the site of operations be free from exhaust gases from a petrol engine, &c. In consequence of this, also, peeling and extraction must be carried out in separate rooms.

(iii) *De-aeration of Juice.*—This is now standard procedure, and is carried out with the object of lessening the extent of oxidative change. The juice is drawn through a fine nozzle into the de-aerating chamber under a vacuum of at least 25″. The spraying method facilitates de-aeration and the removal of dissolved gases.

(iv) *Subsequent Procedures.*—Beyond this point, the method of procedure depends upon the method of distribution of the final product. In the United States of America, by reason of the large population, the ideal distribution is similar to that for milk, and is, in fact, undertaken daily by milk distributors. Under these conditions, the de-aerated juice is forced by means of an inert gas, e.g., nitrogen but preferably carbon dioxide, into sterile containers, and held at 50°F. or

lower until the following day, when it is distributed. At a temperature of 50°F., the keeping quality of orange juice is superior to that of milk at the same temperature.

If the product is to be held indefinitely, it must be further processed (*a*) to inactivate pectic and oxidizing enzymes, and (*b*) to prevent microbial degradation. The best method of ensuring stability in preserved orange juice is still a matter of controversy, but it may be effected in the following ways:—

(*a*) The method of Morris (11) is to concentrate the juice by freezing until a maximum of 45% total solids is reached. The juice is at first frozen rapidly at —28°C. until ice crystals commence to appear, at which point the temperature is raised to —10°C. with the object of obtaining large ice crystals, which may be readily separated from the juice in a centrifuge. This method infringes the "addition and subtraction" rule. Morris claims that the juice may be stored at —10°C. in this way for reasonably long periods, and will, when opened up, compare favorably with fresh juice.

(*b*) *Pasteurization.*—The juice is forced from the de-aerator under pressure of carbon dioxide through the pasteurizer. The flash method is considered to be the most satisfactory, but the temperature to which the juice may be raised is still a matter of controversy. Thirty seconds at 205° F. is stated by Mottern and Loesecke (13) to have no injurious effect on de-aerated juice, and is probably high enough to disorganize both pectic and oxidizing enzymes. The juice is then returned to a holding vat, via the cooling apparatus in which the temperature is reduced considerably (reduced to 150° F., or less), and canned and sealed as rapidly as possible. The container may be of glass, in which case it should be dark or completely enveloped by the label to exclude light, which may, or may not, affect the product (Carpenter (4)). When a metal can is used, it should be citrus enamel-lined in preference to the normal tin lining.

The pasteurization method is now commercial practice, and it is claimed that, by means of it, orange juice may be preserved indefinitely at low temperatures (32° F., or thereabouts), and, while it may open up slightly inferior in quality to fresh juice, it is nevertheless of very pleasing palatability and acceptable to the consumer.

(*c*) *Quick Freezing.*—The utilization of quick freezing methods of juice preservation has been attended by a considerable measure of success. Adverse results that have been obtained are possibly due, not to the process itself, but rather to inconstancy of quality of the original product.

The object of the quick freezing method is to pass the juice through the temperature range so rapidly that a minimum of chemical and physical changes ensue. The bulk of the heat is removed by conduction, either by direct immersion in sodium chloride brine, or by indirect contact with a very cold refrigerant such as calcium chloride brine.

The Birdseye (2) process consists in placing the containers between a moving, metal, double belt which is sprayed with refrigerant in such a way that the product remains dry. The method has been further improved by the introduction of hollow multiple plates in which refrigerative gases are directly expanded.

The fog freezing system or Z process extracts the heat by means of an atomized refrigerant. Various other quick freezing devices are in use, and little difficulty is presented by the process.

The use of helium has been suggested by Snyder and Bottoms (15) as an alternative to other inert gases, both for breaking the vacuum and for the head space in the container. Helium has a thermal conductivity six times greater than that of air, and would therefore assist considerably in the removal of a maximum quantity of heat in minimum time during quick freezing. It is claimed that orange juice sealed in a helium atmosphere for six months appeared to be as fresh as when first extracted.

Successful storage and efficient distribution are as important as the freezing itself. It is suggested that prolonged storage is unsafe above about 5°F., and there is a decided tendency to utilize storage temperatures of — 10°F. to — 5°F. The product should be hard frozen till it reaches the consumer, after which it should be defrosted slowly, preferably in a household refrigerator, and consumed without undue delay.

A suitable type of water-tight, rectangular, seal-end, paper-board cartoon has been developed for the commercial storage and distribution of orange and other fruit juices.

(*d*) *Other Methods.*—Several other methods of preservation may be briefly mentioned. These are either doubtful with respect to their efficacy, or give a definitely inferior product. They are as follows:—

(i) Spray Drying.—The juice is dried by forcing it through a fine nozzle into a hot chamber, and the powdered juice is sealed in tins (Merrill-Soule process). An equivalent quantity of powder is diluted with water before use.

(ii) De-aerated juice is irradiated with ultra-violet light with the idea of destroying or weakening the contained enzymes. Attenuation of micro-organisms is also said to occur, so that subsequent pasteurization may be effected at much lower temperatures (Sperti), viz., 165°F. Joslyn and Marsh (9) have recently investigated the method, and maintain that irradiation induces off-flavours in the juice.

(iii) Pasteurization as before described, plus the addition of 12 lb. of sucrose to the gallon of juice or pasteurization, plus the addition of preservative such as benzoic acid.

5. Position in Australia.

The foregoing brief survey would suggest that the process for the preservation of orange juice as here outlined appears to be satisfactory up to the point of pasteurization. With regard to pasteurization and subsequent cooling and canning, great diversity of opinion is apparent,

e.g., the most suitable temperature for pasteurization is far from definite; the effect of ultra-violet irradiation of the juice is not known with any certainty; uncertainty also exists as to whether the vacuum should be broken, or the whole process, including bottling, should be carried out under a partial vacuum; and finally the temperature of the juice at the time of bottling is a controversial matter, the recommended temperatures ranging from 50° F. to 170° F.

With reference to Australia, it is by no means certain that Valencias would produce the best type of juice. A good deal of experimental blending of oranges of one type from different localities, and of different types, &c., would be necessary before we could arrive at a suitable juice approximating to the ideal. Again, with the English market in view, it would be necessary to make inquiries to determine the degree of sweetness and acidity most pleasing to the palate of the prospective consumer as a whole. As a result of such experience in the United States of America, it has been found that people in the south differ considerably in this matter from those of the north, and the preparation of the juice is modified in accordance with these differences.

Some preliminary investigations have been undertaken in America to determine the suitability of treated orange peel and pulp for stock food, and for conversion to manures. These have been particularly encouraging, and if confirmed locally would materially assist the establishment of the industry.

A final recommendation is a matter which has for some time been considered to be of particular urgency, viz., a complete analysis of the minor constituents of the orange. This phase of the work is stressed both by Joslyn (8) and by Nelson (14). With regard to orange juice preservation, it is essential that the roles of individual constituents in deterioration should be known if an intelligent effort is to be made to combat these changes. A knowledge of the fundamental composition of oranges is likewise necessary before we can apply adequate methods for long-term storage. Such knowledge, moreover, would probably provide the solution of the problem of maturity for market purposes At the present time, maturity is based on sugar/acid ratio, a wholly inadequate indication, since unpalatable fruit is frequently within the scope of the allowable ratio, and *vice versa*.

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The Preservation of Timber Against the Attacks of the Powder Post Borer (*Lyctus brunneus* Stephens) by Impregnation with Various Chemicals.

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Summary.

Successful results in the control of Lyctus beetles have been obtained by impregnating pieces of normally susceptible timber with chemicals.

The successful inorganic chemicals were:—Zinc chloride, sodium fluoride, sodium fluosilicate, and sodium metaborate. Sodium fluosilicate was the most toxic substance, effectively preventing attack at a concentration of 0.024 lb. per cu. ft.

Promising results have been obtained with certain organic chemicals, viz., the chlorinated naphthalenes and organic mercurials such as Lignasan. With the organic compounds, further tests are needed before the relative values of these substances as preservatives against Lyctus beetles can be accurately estimated.

Two methods of testing have been described, one using larvae and the other beetles. The larval test does not give satisfactory results, and does not allow of the ready evaluation of various chemicals for Lyctus control. The beetle test appears to be very satisfactory, and the concentrations of chemicals which inhibit Lyctus infestation have been found to be very low. It is believed that these concentrations would be effective under natural conditions of infestation.

1. Introduction.

The economical treatment of timber, to render it permanently immune to the attacks of the powder post borer, or at least, resistant to them for long periods of time, is a problem which so far has not been satisfactorily solved. In two previous papers (1), the authors have presented the results of studies of the effect of the pore size and the starch content of some Australian timbers upon their liability to attack by Lyctus beetles. This work was carried on in conjunction with tests of certain chemicals to determine their value as preservatives. By the use of preservatives, the natural liability of timber to attack is removed, and fairly permanent immunity can be secured.

The successful use of preservatives depends upon their cost, upon the method of application, and the purpose for which the timber is desired. By varnishing, or otherwise filling the pores, powder post beetles can be prevented from laying their eggs, for it is only in the pores that these are deposited. This procedure is of no use if the timber is already infested, which is not always easy to determine, as the first outward signs of attack appear about 1 year after actual infestation occurs. Timber may be sterilized by heat and then varnished or painted over to prevent re-infestation. Unfortunately, the sterilization does not render the timber immune to further attack. Varnishing or filling is useful when dealing with small articles of considerable value, but it is not practicable when dealing with large sizes and is not of much use if the timber is subsequently cut and worked, thus exposing fresh surfaces for infestation.

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To preserve timber from the powder post borer effectively, it must be treated so that it will be repellent to the insects, which will thus avoid it, or it must be given poisonous properties, which will prevent the eggs from hatching or kill the larvae before they have done any appreciable damage.

This condition could be obtained by thoroughly impregnating the susceptible timber (sapwood) with some suitable preservative substance. With thorough impregnation, the disadvantages of surface treatments are removed. The timber can then be worked freely, and the danger of exposing susceptible surfaces for infestation due to the destruction of the surface coating by the action of the weather or other influences is no longer a serious matter. There is very little information available on this aspect of the problem. Most publications dealing with the control of the powder post borer discuss remedial measures more fully than preventative ones.

2. Review of Literature.

Attempts to preserve timber from destructive influences were made in the days before the Christian era. For a general account of timber preservation practice, reference may be made to Weiss (2). A considerable number of publications which need not be listed here have advocated methods of Lyctus control which may be considered under two headings.

(i) Methods for Treatment of Infested Wood.

(i) *Sterilization by heat.*—This is effective, and, provided the necessary apparatus is available, quite cheap.

(ii) *Sterilization by fumigation.*—This is quite effective if done well. Its chief application is for the treatment of valuable wooden articles, the appearance of which would be likely to suffer if other methods were used.

(iii) *Painting, dipping, or spraying with preservatives.*—With these methods, it is difficult to obtain sufficient penetration to ensure that the treatment will be effective. In addition, the appearance of the timber may be adversely affected by certain preservatives.

(ii) Methods for Preventing Attack.

(i) *Removal and destruction of sapwood at the mills.*—While there is much to be said for this practice, which removes the breeding ground of the pest and also ensures that no sawn timber will be attacked, it is wasteful and, in many cases, heavy losses are incurred, particularly where valuable cabinet timbers with wide zones of sapwood are being exploited.

(ii) *Seasoning the timber in such a manner as to render it immune to attack.*—The procedure suggested to date involves storing for months under water, or in the log with the bark intact. These methods have not so far met with much approval and have not been used commercially as far as is known. They are probably not very certain in their effect, and the work must be carefully carried out.

(iii) *Painting, dipping, or spraying with preservative substances.*—The effects so produced are only temporary, and in many cases the appearance of the timber is unfavorably affected by the treatment. Once the preservative coating is broken, the timber beneath is exposed to attack.

(iv) *Impregnation with preservative substances.*—The literature dealing with the impregnation of timber to resist Lyctus attack is very limited in extent.

In 1913, Pearson (3) steeped tea box shooks in solutions of copper sulphate and zinc chloride (concentrations 1 per cent., 2 per cent., and 3 per cent.) and alum (concentration 3 per cent.) for 24 hours. Apparently, cold solutions were used. The box shooks, which were cut from Indian timbers, were probably all heartwood (truewood). After treatment, the specimens were thoroughly dried and then exposed in likely situations for borer attack. The insects are not specified. After five months the treated shooks were still borer-free. In view of the heavy losses stated to occur owing to the attacks of borers, when tea shooks were stored, the treatment appears to have been temporarily effective. No estimate was made of the absorptions of the various chemicals. The service test was not finished when the article was written, so that the relative efficiencies of the different concentrations cannot be discussed. In 1928, Munro (4), in a discussion on the control of Lyctus beetles, mentioned zinc chloride, sodium fluoride, and sodium fluosilicate as the only possible insecticides in view at the time and which were capable of widespread commercial application. Bulletin No. 2, 1928, British Forest Products Research Board, "Lyctus Powder-Post Beetles" (5), refers to experiments being carried out with oak and ash sapwood. Specimens were treated by the hot and cold bath process with 2 per cent. and 4 per cent. solutions of zinc chloride and then exposed to the attack of Lyctus beetles. The results of this test are not yet available.

The Report of the British Forest Products Research Board for 1929 (6) discussed the results of tests in which specimens of oak, treated by the full cell process with solutions of zinc chloride and a proprietary preservative, were exposed to the attacks of Lyctus beetles. In 1932, the same matter was discussed at greater length by Cann (7). Two series of experiments, using large timber samples in cages and small samples of sapwood only, exposed to Lyctus attack in boxes, were carried out. The small samples were cut at intervals to follow the development of the larvae. The results indicated that treatment of specimens with 0.1 to 2.0 per cent. zinc chloride solutions did not prevent egg-deposition, hatching, or initial feeding of larvae. It was found, however, that the larvae in the specimens treated with this range of solutions eventually died (absorptions of solutions are not given). Some larvae were able to live three months in specimens treated with 0.2 per cent. solution of zinc chloride, and in specimens treated with a 2.0 per cent. solution, some larvae survived a month. The proprietary salt, of unknown composition, was used in concentrations of 0.05 to 1.0 per cent. Hatching did not occur in specimens treated with solutions stronger than 0.2 per cent. concentration. The longest life recorded for any larva was one month in a specimen treated with 0.05 per cent. solution. It is unfortunate in this case that the absorptions of the solutions per specimen were not recorded, as it is impossible to judge from the concentrations of the solutions the final concentration of the preservatives in the treated specimens. Nevertheless, zinc chloride must be effective in very dilute concentration, for, assuming that 1 cubic foot of oak sapwood absorbs 50 lb. of solution, which is probably much greater than the actual figure, the absorption of dry salt would be 0.05 lb. per cubic foot in the

case of the 0.1 per cent. solution of zinc chloride, and 0.025 lb. per cubic foot of dry salt in the case of the 0.05 per cent. solution of proprietary preservative. For general preservation purposes for protection against decay, absorptions of zinc chloride of 0.5 to 0.75 lb. dry salt per cubic foot are usually recommended. It appears, therefore, that in relatively low concentrations zinc chloride has a detrimental effect on young Lyctus larvae, although it should be observed that some boring is possible even with a 2 per cent. solution.

Beeson (1935) (8) states that the addition of 5 per cent. of sodium fluoride to the dry mix in preparing glue for plywood prevents the larvae of the boxwood borer (*Heterobostrychus*) from passing through the glue from one veneer to another.

3. Experimental Work.

(i) Introduction.

The work reported herein was commenced in the summer of 1932, at which time the significance of starch in relation to Lyctus attack was not fully appreciated. A large number of test pieces of impregnated sapwood and untreated controls were submitted to Lyctus beetle attack in the summer of 1932-33. It was later found that a number of these specimens did not contain sufficient starch to render them susceptible to attack, and the results of the tests were therefore largely useless. In the present paper, these results from the starch-free samples used against beetles are not further discussed, and only specimens containing sufficient starch to render them liable to attack, if untreated, are included in the results. The work was continued during the years 1933, 1934, and 1935.

(ii) Timber Used.

All experiments were conducted using starch containing sapwood of *E. obliqua*, a timber which is known to suffer frequently from severe Lyctus infestation. The timber contains large pores, the range of the maxima of the minimum pore diameters being from 205μ to 240μ.

The starch content of each individual specimen was tested before submission to test. Tests were also made on some specimens both before and after impregnation with preservatives or the solvents used, but in no case did the treatment appear to have any noticeable effect on the starch content. Some of the specimens contained gum veins. These were only small, and they appeared to have no effect on subsequent infestation, when this occurred. Timber infested under natural conditions frequently contains gum veins.

Before treatment, the sapwood was air seasoned to about 12 per cent. moisture content. Test specimens of sapwood about 8.5 cms. x 3.5 cms. x 1.25 cms. were then cut and tested for starch.

(iii) Method of Impregnation.

Test specimens were carefully measured and weighed, and then immersed in a boiling solution of preservative. In the case of water-soluble preservatives, treatment was carried out in open vessels, provision being made to prevent concentration of the solutions by evaporation of solvent. For benzol- or alcohol-soluble materials, the treatment was made under a reflux condenser. The timber specimens

were boiled in the solutions for one hour and then allowed to cool down in the solutions to room temperature. After removal from the impregnating bath, the specimens were wiped to remove free liquid on the surface, and re-weighed. The absorption of preservative was then calculated in terms of pounds of preservative per cubic foot of wood. In general, a 1 per cent. aqueous solution gave an absorption of about $\frac{1}{2}$ lb. of preservative per cu. ft., other concentrations giving proportional absorptions. Complete penetration was obtained in all test specimens.

After treatment, the specimens were again air-dried, after which they were trimmed to a size of about 8 cms. x 3 cms. x 1 cm., wood being removed from all surfaces so as to reduce the possibility of there being higher surface concentrations due to capillary liquid phase movement during drying.

Untreated controls, and controls which had been treated under identical methods using the solvents alone, were also prepared.

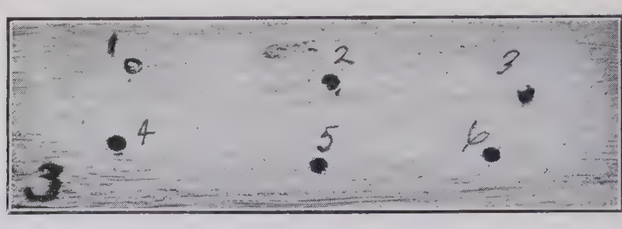
(iv) Larval Tests.

(i) *Preliminary test.*—The use of Lyctus larvae as a means for testing and evaluating wood preservatives suggested itself as a result of seeing some tests being made in Sydney by Mr. H. Beale of Beale and Co. Mr. Beale had introduced Lyctus larvae into holes in pieces of sapwood and observed that boring was continued by some of the larvae. A preliminary test was made by introducing larvae into small slightly tapering holes with a top diameter slightly greater than that of a larva. This test showed that the larvae commenced to bore into the sapwood almost immediately and eventually emerged as mature beetles. Frass was ejected from the awl holes within a short time after the larvae were introduced. Frequently, a pile up to $\frac{1}{8}$ inch in height was extruded within 24 hours. Larvae that were placed in sapwood dyed with aniline dyes showed a strong colouration of the gut within twelve hours, indicating that a proportion of the chewed wood at least was quickly passed into the digestive tract. The introduction of larvae into treated sapwood therefore appeared to offer a possible method for the relatively quick and ready evaluation, and comparison of the toxicity of various chemicals. It also appeared that it would overcome one great disadvantage associated with testing against Lyctus beetles, in which, owing to the relatively long life cycle of the insect, considerable time must elapse before results are obtained. In addition, work with beetles can only be carried out during the summer months, and supplies of paired beetles are frequently difficult to obtain. The method of larval testing was therefore investigated, and a number of tests made to determine if possible the comparative toxicities of various chemicals.

(ii) *Preparation of specimens for test.*—Small blocks of sapwood were treated with preservatives as described in sections (ii) and (iii) on page 40. After drying and removing the outer surfaces, six awl holes, evenly spaced, were bored in the wide face of each specimen (see Fig. 1) to a depth of about 3 mm. The holes were approximately 2 mm. in diameter on the surface and tapered to a point at the bottom.

(iii) *Choice of larvae and test of method.*—In the first test of preservatives made in 1932-33, the larvae were grouped into three general size classes, namely, small, medium, and large, and two of each

size were introduced into each specimen. Results indicated that the larger larvae in all cases bored very little and quickly pupated. In this series, no preliminary tests were made on the starch content of the individual specimens, and it appeared from the controls that the presence or absence of starch had little effect on the results obtained. Subsequent experiments were therefore made to determine the most satisfactory size of larvae for testing and also the effect, if any, of the presence or absence of starch upon larval behaviour.



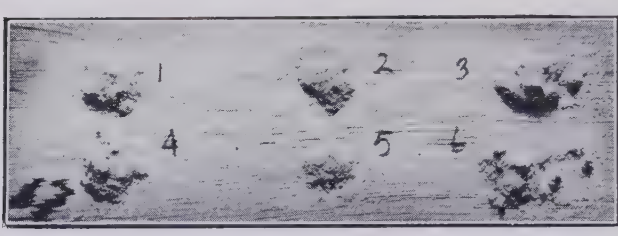


FIG. 1 (*a*) (top)—Larval test specimen showing awl holes and larvae commencing to bore (as indicated by slight amount of frass.)

(*b*) (bottom)—Specimen showing frass extruded by larvae from awl holes.

Two series of experiments were prepared, the first with very small larvae and the second with those classified as small to medium.

The larvae were obtained from badly infested sapwood of various species of Australian timbers. This material crumbled and broke up readily, and it was possible to remove the larvae very easily with a minimum amount of handling by using a moistened camel hair brush. Five apparently healthy larvae of the size class required were placed on a tared watch glass, weighed, and then carefully inserted head downwards in awl holes made in prepared specimens of starch-free and starch-containing sapwood. At weekly intervals, a specimen was taken from the test series, the larvae removed (by opening up the specimen if necessary), and then re-weighed. In the first test, the dishes containing the specimens were kept at room temperature, while in the second test they were maintained at 75°F. for the first nine weeks. The results of the tests are shown in Tables 1 and 2.*

A study of Table 1 indicates that for the first three weeks very small larvae, in starch-containing wood, did not lose in weight. Beyond this time no weights were obtainable, but some further boring occurred and in one case a pupa was found. The larvae in starch-free wood were of less weight after periods up to eight weeks, and at the conclusion of the test a greater number of them were found to be shrivelled or dead than in the case of those larvae in the starch-containing specimens.

* See page 49.

With both starch-containing and starch-free wood, the total amount of boring was small, even in specimens allowed to stand for a period of twelve months, and in no specimen was the life cycle of the insect carried to the beetle stage.

A study of Table 2 shows that, in the starch-containing specimens, the larvae increased in weight, the longest period at which actual weights could be obtained being three weeks. Beyond this time, the larvae must have increased in weight, as extensive boring occurred and emergence of beetles took place. In the starch-free specimens, a definite loss of weight occurred during the first three weeks. At six weeks, some beetles had emerged. An examination of the specimens, however, showed that little boring had occurred. Apparently, the larger of the small to medium larvae were able to mature with very little additional nutriment. The beetles that emerged from the starch-free wood were not significantly different in size from those that emerged from the starch-containing wood. The most significant fact in this second test was the difference in extent and amount of boring, that in the starch-containing specimens being by far the greater.

A comparison of results from the tests with very small and with small to medium larvae definitely shows the former to be unsuitable for testing purposes. The very small larvae cannot satisfactorily establish themselves when transferred to other pieces of sapwood. Small to medium sized larvae can be satisfactorily transferred and are apparently resistant to adverse conditions, as shown by their ability to complete the life cycle in starch-free wood.

It appears from the foregoing results that, in tests of preservatives made with larvae, starch-containing specimens will be far more satisfactory than those which are starch-free. Development appears to be more normal in starch-containing specimens, and the greater extent of boring should be reflected in the effect of the preservatives on the larvae, as with greater boring obviously more impregnated sapwood will pass through the gut. There appears to be a tendency in starch-free wood for larvae to undergo metamorphosis with a minimum of boring, and it is thought that the concentrations of chemicals which would be found effective in starch-containing wood might not be effective in starch-free wood, owing largely to the reduced amount of toxic material passed through the digestive tract.

Complete lack of boring by larvae placed in chemically treated wood, particularly that containing starch, can be attributed to the deterrent properties of the chemical with which the wood is treated, provided that the larvae are of sufficient size, i.e., small to medium. Furthermore, in starch-containing wood, the amount of boring may be taken as indicative of the deterrent effect of the preservative chemical under test.

(iv) *Test Method Adopted.*—Small to medium sized larvae were used in all tests, these being carefully removed from Lyctus-infested wood and handled with a moist camel hair brush. In each specimen, six larvae were inserted into six awl holes made on one of the wide faces (see Fig. 1). The test specimens were inspected on the following day and at frequent intervals thereafter. The quantity of frass in each hole was recorded as an indication of the amount of progress made by each larva. Where larvae died shortly after insertion into the awl holes or failed to produce any frass at all, they were removed and replaced by fresh ones. In some cases more than one replacement was made. Where mortality was rapid and complete throughout a specimen (no boring),

fresh holes were bored, and another set of larvae inserted in these. By these means, any inherent weaknesses in the original larvae used or unfavorable characteristics of the awl holes were eliminated. All specimens were placed and kept in closed petri dishes.

(v) *Examination of test specimens and recording of results.*—The test specimens were regularly inspected and notes made on frass formation in the awl holes, and the emergence of beetles if any recorded. The specimens were retained until beetles had ceased to emerge or until there was no probability that they would emerge at all. They were then split up, and the amount of boring made by each larva was measured and recorded.

The results of the various tests are given in Table 3 and discussed later in section 4.

(v) Beetle Tests.

It was appreciated that larval tests would not necessarily give a true indication of the toxicity of various preservatives for preventing attack, as newly hatched larvae would presumably be less resistant to adverse conditions than those of greater maturity. Beetle tests, however, are more difficult to carry out, as they require considerable stocks of the insects, and these are only available in quantity during a limited period of the year. The method of testing with beetles is given in detail below.

(i) *Preparation of specimens for test.*—In the early 1932-33 series of tests, the treated and untreated specimens were dressed on all faces and edges, and the ends were cleanly cut so as to expose the pores. In 1932, Kojima (9) stated that the longitudinal surface of the wood appeared to be preferred for oviposition, especially if it was rough. All later test specimens were therefore prepared by dressing one face and one edge and cleanly cutting one end, the remaining face, edge, and end being left rough sawn. For convenience, a standard dimension of 8 cms. x 3 cms. x 1 cm. was adopted for all specimens, this size conveniently fitting into a 9 cm. x 2 cm. deep petri dish in which all specimens were placed and kept during, and after, exposure to the beetles.

(ii) *Preparation of Petri dishes.*—Lyctus beetles cannot move about easily on smooth glass surfaces, and in order to give them ready access to the wood specimens the bottom of each petri dish was covered with paper. This paper was evenly glued to the bottom of each dish with Canada balsam or starch paste, and no unevenness or looseness was permitted, as it was found that the insects would congregate if possible between the paper and the bottom of the dish. After gluing, the dishes were placed in an oven at 100°C. for some hours to dry the adhesive and to drive off any fumes from the Canada balsam which might be harmful to the insects.

In the 1932-33 series of tests, each specimen was laid flat on the bottom of the dish, and it was noticed that the beetles tended to congregate under any slightly raised portion. In all later tests, the specimens were rested on two short pieces of wire (14 gauge), placed about 5 cms. apart and glued to the paper, to prevent their movement (see Fig. 2). This allowed the insects to have access to all surfaces of the specimen. When exposed to the light, they showed a marked preference for the under surface, in accordance with their well-known light-shunning habit.

(iii) *Selection of beetles.*—The necessary beetles were obtained from naturally infested timber samples, which were kept in large glass accumulator jars. As these specimens were taken from a number of different species of timber from all States of the Commonwealth, precautions were at first taken to avoid possible mixing of different species of Lyctus. Only beetles obtained from any one set of samples of the same species of timber were used for a given test specimen.

FIG. 2.—Test specimen submitted to Lyctus beetle attack in petri dish container. Note papered bottom and wire supports for specimen.

A number of insects, representative of those obtained from the different species of timber, were collected and forwarded to Dr. R. C. Fisher, Entomologist of the Forest Products Research Laboratory, England, who kindly examined all the material, and reported that only one species was present, namely, *Lyctus brunneus* Steph. The absence of other species removed the danger of possible sterility, and it was then possible in the later work to mix beetle stocks from the various species of timber. All beetle stock used was carefully examined throughout the series of tests. In all cases, the only species found was *L. brunneus*.

The jars containing the infested wood were examined daily during the emergence period, and all beetles present carefully removed with a small, moistened, camel hair brush. Only sound, active individuals were retained, any which were injured or misshapen being discarded. The beetles for test purposes were all placed in a stock dish. Pairing under such conditions was observed to take place almost immediately, or at the most within several hours. The pairs were carefully removed and transferred to dishes containing the test specimens. Ten such pairs were placed with each test specimen. Each dish was then transferred to a shelf, which was screened with black cloth in order to exclude light as much as possible. This practice was adopted in an

attempt to distribute the possible attack over all surfaces by reducing the tendency of the beetles to congregate in shaded portions of the specimen.

Unpaired insects remaining from one day's collection were kept till the following day, and augmented by the addition of fresh stock. Any which still remained unpaired at the end of the second day were discarded.

(iv) *Method of examination and recording of results.*—Test specimens exposed to the attack of beetles were left for a period sufficiently long to allow the second generation of beetles, if any, to emerge. The specimens were then cut into pieces and the general extent of the damage recorded. Notes were also made of beetle emergence, but the data so obtained did not appear to have any significence, or to be related to the value of the preservative. The most important criterion from the economical standpoint was the actual extent of damage to the specimen. The detailed results of the beetle tests are given in Table 4, and are discussed below.

4. Discussion of Experimental Results.

(i) Larval Tests.

The results of the larval tests are given in Table 3, the inorganic and organic chemicals tested being grouped separately. The significant data in assessing the value of a preservative by this method of testing are:—the extent of boring, the number of larvae replaced, and the number of beetles subsequently emerging. Of these the extent of boring is the most important.

A study of Table 3 shows that, of the chemicals tested, and the concentrations used, only mercuric chloride, sodium fluoride, and sodium fluosilicate prevented any boring, the concentrations required being high. These chemicals also appeared to have the greatest initial effect on the introduced larvae which were replaced more frequently than for any other chemical, although it will be noted that the organic mercurials (Lignasan, &c.) were also toxic to the larvae.

In some cases, variable results were obtained, a very small amount of attack being sometimes recorded in specimens containing a concentration greater than that which in another specimen had prevented all attack.

From the data available, it is extremely difficult to obtain even a rough classification of the toxicity of the various chemicals used towards Lyctus larvae. This difficulty is due to the apparent similarity in damage done to the specimen, even at widely varying concentrations. The method of testing the relative value of chemicals by using larvae was of distinct value in the early stages of the work, and before the method of beetle test was fully developed. In the light of the full results, it does not appear to be of practical value, and further tests are not contemplated.

(ii) Beetle Tests.

The primary factor in assessing the value of the chemically treated specimen tested against Lyctus beetles, is the extent of borings made by the larvae. In Table 4, the extent of the damage has been recorded for all specimens that were submitted to attack. No attack is obviously the most desirable case from the point of view of the timber user. Five grades of attack were recognized, namely, "trace," "slight," "moderate,"

" severe," and " destroyed." The amount of damage recorded in the " trace " grade is practically negligible, and difficult to see with the naked eye. It would not affect the value of the wood for any purpose. The borings present are apparently those of very young, almost newly hatched larvae. Although a close examination was made of specimens containing this grade of damage, no live larvae could be found, and apparently all larvae had died at a very early stage. The method of test is considered to be severe, as the beetles were given no alternative but to attack the treated specimens, and under ordinary conditions of infestation, it is believed that sapwood treated with chemicals in those concentrations which have been successful in these tests in preventing all but a trace of damage would be immune from attack. Actually, on account of the possibility of the beetles being able to exercise a preference, even much lower concentrations may inhibit damage.

It will be noted in Table 4 that some chemicals were tested over a wider range of concentrations than others. These chemicals, in addition to their promise of value as insecticides, were cheap and had no effect on the colour or the staining and finishing properties of the wood into which they were impregnated. It is also probable that some of those chemicals which have been tested in few concentrations would be toxic in relatively small amounts, but a number of these chemicals have various undesirable characteristics. A study of Table 4 indicates four common inorganic preservatives of likely value. Sodium fluosilicate gave complete protection at a concentration of only 0.024 lb. of dry salt per cu. ft of wood, while borax, sodium fluoride, and zinc chloride gave effective protection at concentrations of 0.04, 0.05, and 0.1 lb. of dry salt per cu. ft. of wood respectively. All of these preservatives are cheap, and their commercial use, particularly in the low concentrations required is entirely practicable. Mercuric chloride also appears to be very toxic but possesses other characteristics that render it unfit for general use. Other chemicals, such as calcium chloride, magnesium sulphate, and sodium chloride, appear to have very little toxic value.

Of the organic chemicals, it appears from the data available that chlorinated naphthalenes (such as Halowax 1012 and Seekay Wax R93) and the organic mercurials (Lignasan, 745 A.C., and 745 A.B.) will be effective in low concentrations. The chlorinated naphthalenes, owing to their solubility in organic solvents such as benzol, naphtha, &c., may be particularly useful for the treatment of fabricated articles containing sapwood where treatment with water solution may be deleterious. The toxicity of Lignasan is very interesting. This material is reported to contain only about 4 per cent. of ethyl mercury chloride, the balance being some inert substance. The nature of this inert substance and its effect on Lyctus infestation is not known. As the material is being largely used for sap stain prevention, it is possible also that it may be developed for insect proofing. Other chemicals used for sap stain prevention, such as sodium orthophenylphenate and the chlorphenates, do not appear to be very effective even in concentrations as high as 1 lb. per cu. ft. of sapwood.

Considerable attack occurred in all the control specimens, independently of the solvent with which these may have been treated. The fact that all controls gave positive results is an indication of the satisfactory nature of the test conditions used to obtain Lyctus infestation.

(iii) Relation between Beetle and Larval Tests.

Comparison of the results given in Tables 3 and 4 shows that there is apparently little relationship between tests with beetles and tests with larvae. In the case of sodium fluosilicate, particularly, the larval test showed this substance to be effective at a concentration of about 0.4 lb. per cu. ft., whereas beetle tests show a toxicity of less than 0.024 lb. per cu. ft. With borax, appreciable larval damage occurred at 2.3 lb. per cu. ft., whereas less than 0.04 lb. was effective against beetles. It is obvious from this and also the results of the tests of various sized larvae that, with increase in age, the larvae develop a marked ability to withstand adverse conditions. As would be expected, the newly hatched larvae are the least resistant to chemicals or to other adverse conditions.

A study of the results from the larval test alone indicated their unsatisfactory nature, and, when the results so obtained are compared with those from the beetle test, their value is further decreased. It appears essential, if satisfactory comparisons of toxicity are to be obtained, that the beetle test should be employed, although this method requires more time and can only be carried out during a restricted period of the year.

5 Acknowledgments.

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TABLE 1.—RESULTS OF TESTS USING VERY SMALL LARVAE.

Species of sapwood.	Specimen No.	Initial weight (5 larvae). (Mgms.)	Final weight (5 larvae). (Mgms.)	Period between initial and final weights. (Days.)	Remarks.
E. obliqua—starch content medium	1	6·0	6·0	7	All active at end 7 days, only 1 hole contained frass. Replaced after 7 days and at end of 3 weeks weighed 5·0 mgms.; no boring
	2	7·2	6·6	14	All active at end 7 days, 1 hole filled. At 14 days 1 dead and only 1 hole filled, all inactive, slight boring 1 hole, 5 mms.
	3	4·6	4·6	21	Four active, 1 inactive at 7 days. 3 active at 14 days and holes contained some frass. At 21 days 4 inactive, 1 larva bored 1·5 cms., hole filled
	4	7·0	*	28	All active at 7 days, 2 holes just filled. Similar condition at 14 days. At 21 days 3 inactive. At 28 days only 3 larvae found, 1 dead. Total boring 45 mms. in 2 larvae
	5	4·6	*	56	Two active at 7 days, 1 hole filled at 14 days, rest working. At 21 days 3 active, 2 inactive. At 28 days all inactive. At 56 days 4 larvae and 1 pupa found very shrunken, boring almost nil
	6	5·4	*	..	At 7 days 3 active, 2 inactive. At 28 days all inactive. At 12 months no larvae found, boring about 6 cms. for 2 larvae only, no beetles
E. obliqua—starch content nil	7	6·4	6·0	7	One larva dead, remainder active, but only 2 holes contained frass, no boring
	8	5·0	4·1	14	All larvae covered with frass, but only 1 hole filled after 7 days. At 14 days 1 active, remainder inactive, no boring
	9	3·0	2·3	21	All except 1 active at 7 days, at 14 days 2 holes partly filled frass, 3 inactive. At 21 days similar, all alive, total boring 5 mms.
	10	6·0	4·6	28	All active at 7 days, 1 hole filled at 14 days, all filled at 21 days, at 28 days 1 hole overflowing. Total boring 11 mms.
	11	3·8	*	56	At 7 days 3 active, 2 inactive, at 21 days ditto, 28 days 2 active 3 inactive, 56 days 4 larvae found, 2 very shrivelled. Total boring 8 mms.
	12	5·2	*	..	At 7 days 4 active 1 inactive, at 14 days 4 holes filled with frass, 28 days 4 still active, 1 inactive. After 12 months no larvae found, total boring about 6 cms. No beetles.

* No weight obtainable.

TABLE 1.—RESULTS OF TEST USING VERY SMALL LARVAE—*continued.*

Species of sapwood.	Specimen No.	Initial weight (5 larvae). (Mgms.)	Final weight (5 larvae). (Mgms.)	Period between initial and final weights. (Days.)	Remarks.
E. regnans—starch content nil	13	5·2	5·2	7	All active, only 1 hole filled with frass. Replaced after 7 days and at end of 3 weeks weight 3·7 mgms. Slight boring.
	14	6·2	3·2	14	At end of 7 days 1 active and hole filled with frass, 4 inactive. At 14 days 2 active, balance shrivelling and becoming brown, slight boring 5 mms., 1 hole
	15	6·4	5·0	21	At end 7 days 3 inactive 2 active, 1 hole filled, other partly, at end 21 days similar, 1 larva left hole and found dead. Total boring 5 mms.
	16	5·4	4·0	28	At end 7 days 2 inactive 2 filled, 1 active, at 14 days 3 inactive, at 21 days 2 active, 3 inactive, 28 days all inactive, total boring 12 mms.
	17	5·0	1·5	56	At end 7 days 3 inactive 2 active, at 14 days as before, at 21 days 2 holes partly filled, rest inactive, at 28 days 2 holes filled. After 56 days 3 larvae badly shrivelled, 2 normal. Slight boring
	18	2·2	*	. .	At end 7 days 1 active, rest inactive. At 14 days slight frass in 4 holes, 28 days as at 14. After 12 months no larvae found, total boring almost nil.

* No weight obtainable.

Table 2.—Results of Test Using Small to Medium Larvae in Starch Containing* and Starch Free* Sapwood of E. Obliqua.

Specimen No.	Initial Weight (5 larvae). Mgms.	Final Weight (5 larvae). Mgms.	Period between Initial and Final Weights. Days.	Remarks.
1	11·4	11·7	7	All active at 7 days, total boring 1.5 cms.
2	10·3	11·2	21	At 21 days 2 larvae found slightly crushed, 2 pupated, considerable boring
3	11·5	†	42	At 42 days only 2 larvae found plus 1 beetle. Weight of 2 larvae 9·0 mgms., considerable boring > 16 cms.
4	14·4	†	63	At 63 days 1 large larvae, 1 pupa, and 2 medium size and 1 small beetle found in pupal chambers, extensive boring
5	10·8	†	..	Five small beetles emerged, extensive boring; specimen retained and eventually very extensively eaten by second generation of larvae
6	11·4	†	..	Three medium and 2 small beetles emerged, extensive boring; specimen retained and eventually very extensively eaten by second generation of larvae
7	8·4	7·6	7	All active at 7 days, total boring 0·6 cms.
8	10·5	8·0	21	At 21 days 2 small larvae and 3 pupae found
9	7·4	†	42	At 42 days 2 dead larvae found in dish, 2 small larvae and 1 beetle, flight hole at end of specimen, total boring about 2 cms.
10	14·2	†	63	At 63 days 1 medium and 3 small beetles, remaining larvae not found. Boring slight, about 1 cm.
11	8·4	†	..	One medium and 2 small beetles emerged, total boring all larvae 3 cms.

* Specimens 1 to 6, inclusive, starch content medium. Specimens 7 to 11, inclusive, starch content nil.

† No weight obtainable.

TABLE 3.—RESULTS OF TESTS OF VARIOUS PRESERVATIVES AGAINST LYCTUS LARVAE.

Note.—Six larvae initially introduced into each specimen.

Name of Preservative.	Absorption of Preservative. (lb./cu. ft.)	Starch Content Specimen.	Number of Larvae Replaced.	Number of Beetles Emerged.	Extent of Boring.
		INORGANIC.			
Arsenious oxide ..	0·4	Trace ..	4	2	Trace
	0·7	,, ..	6	6	,,
Barium chloride ..	0·35	Slight ..	0	4	Extensive
	0·8	Trace ..	1	4	,,
	1·8	Dense ..	0	6	Moderate
	2·2	Trace ..	0	4	,,
Copper sulphate ..	0·4	Medium ..	1	5	Moderate
	0·8	Trace ..	0	6	,,
	1·6	,, ..	0	6	Extensive
Mercuric chloride ..	0·2	Trace ..	5	1	Trace
	0·4	Slight ..	3	0	Slight
	0·8	Slight-medium	15	0	Nil
Sodium fluoride ..	0·4	Dense ..	1	0	Moderate
	0·4	Medium ..	2	1	Trace
	0·7	,, ..	1	2	Moderate
	1·1	,, ..	6	0	Nil
	1·7	Nil	4	0	Slight
Sodium fluosilicate ..	0·05	Medium ..	1	4	Slight
	0·25	,, ..	1	4	,,
	0·4	,, ..	18	4	,,
	0·4	,, ..	2	3	Nil
	0·8	Slight ..	10	0	Trace
Sodium metaborate ..	0·4	Slight ..	0	0	Moderate
	0·4	Slight-medium	0	0	Trace
	0·8	Trace ..	4	0	Moderate
	1·4	Slight ..	2	0	Trace
	2·0	,, ..	2	0	Slight
	2·3	Trace ..	1	0	Moderate
Zinc chloride ..	0·4	Trace ..	0	6	Moderate
	0·4	Nil	0	6	,,
	0·8	Trace ..	0	3	,,
	1·3	Slight-medium	0	4	Slight
	1·6	Trace ..	0	4	Moderate
	2·9	Nil	0	3	Slight
		ORGANIC.			
Chestnut wood extract	0·25	Trace ..	0	6	Moderate
	0·5	Slight ..	1	5	,,
	1·0	Trace ..	1	5	,,
Chlorinated naphthalene (Halowax 1012)	0·02	Medium ..	0	5	Extensive
	0·3	Slight ..	0	6	Slight
Chlorinated naphthalene (Seekay Wax R 93)	0·025	Slight ..	4	5	Moderate
	0·25	Medium ..	4	1	,,

TABLE 3.—RESULTS OF TESTS OF VARIOUS PRESERVATIVES AGAINST LYCTUS LARVAE—*continued.*

Name of Preservative.	Absorption of Preservative. (lb./cu. ft.)	Starch Content Specimen.	Number of Larvae Replaced.	Number of Beetles Emerged.	Extent of Boring.
		ORGANIC—*continued.*			
α–Chlornaphthalene ..	0·03	Slight ..	0	6	Moderate
	0·3	,, ..	0	2	Trace to slight
p–Dichlorphenol ..	0·03	Slight ..	0	6	Moderate
	0·3	,, ..	0	6	Extensive
β–Naphthol ..	1·9	Nil	1	4	Extensive
Sodium–2–chlor–o–phenylphenate	0·25	Dense ..	3	4	Extensive
	0·5	,, ..	3	4	,,
	1·0	,, ..	4	5	,,
Sodium–o–phenyl-phenate	0·25	Dense ..	2	0	Slight
	0·5	,, ..	3	3	,,
	1·0	,, ..	3	3	,,
Sodium tetrachlorphenate	0·25	Dense ..	3	2	Extensive
	0·5	,, ..	1	4	,,
	1·0	,, ..	0	0	Slight
Tannic acid ..	0·25	Slight ..	1	5	Extensive
	0·5	,, ..	1	5	Moderate
	1·0	Medium ..	1	4	,,
	2·0	Slight ..	1	3	,,
Lignasan (contains ethyl mercury chloride)	0·25	Dense ..	3	2	Slight
	0·5	,, ..	0	2	,,
	1·0	,, ..	4	1	,,
745 AB (contains ethyl mercury phosphate)	0·25	Dense ..	5	1	Slight
	0·5	,, ..	0	0	,,
	1·0	,, ..	6	1	,,
745 AC (contains ethyl mercury chloride)	0·25	Dense ..	4	2	Slight
	0·5	,, ..	6	0	,,
	1·0	,, ..	3	0	,,
		CONTROLS.			
Water	..	Slight ..	0	5	Moderate
		Medium ..	1	5	Extensive
Ethyl alcohol ..	..	Slight ..	0	6	Moderate
		Medium ..	0	6	Extensive
Benzol	..	Slight ..	1	6	Moderate
		Medium ..	0	6	Extensive

TABLE 4.—RESULTS OF TESTS OF PRESERVATIVES AGAINST LYCTUS BEETLES.

Name of preservative.	Absorption of preservative (lb./cu. ft.).	Starch content specimen.	Extent of damage to test specimens.
		INORGANIC.	
Barium chloride	0·4	Dense	Trace
	1·0	Medium ..	,,
	1·9	,, ..	Nil
Calcium chloride	0·2	Medium ..	Destroyed
	0·4	,, ..	Moderate
	0·9	,, ..	,,
Magnesium sulphate	0·05	Medium ..	Moderate
	0·2	,, ..	,,
	0·8	,, ..	Slight
Mercuric chloride	0·25	Dense	Nil
	0·5	,, ...	,,
	1·0	,, ...	,,
Sodium chloride	0·05	Medium ..	Destroyed
	0·2	,, ..	Moderate
	0·3	,, ..	Slight
Sodium fluoride	0·05	Medium ..	Nil
	0·1	Dense	,,
	0·2	Medium ..	,,
	0·4	,, ..	,,
	0·45	,, ..	,,
	0·45	,, ..	,,
	0·9	,, ..	,,
	1·1	,, ..	,,
	1·8	Slight	,,
Sodium fluosilicate	0·024	Medium ..	Nil
	0·05	,, ..	,,
	0·06	,, ..	,,
	0·1	,, ..	,,
	0·2	,, ..	,,
	0·2	,, ..	,,
	0·4	Dense	,,
	0·5	Medium ..	,,
Sodium metaborate	0·04	Dense	Trace
	0·1	Medium ..	Nil
	0·3	,, ..	,,
	0·3	Slight	,,
	0·4	Medium ..	,,
	1·0	Slight	,,
	1·4	Slight-medium ..	,,
	1·9	Medium ..	,,
	2·8	,, ..	,,
Zinc chloride	0·1	Medium ..	Trace
	0·2	,, ..	,,
	0·4	Trace-medium ..	Nil
	1·3	Medium ..	,,
	2·0	,, ..	,,
	2·9	,, ..	,,

TABLE 4.—RESULTS OF TESTS OF PRESERVATIVES AGAINST LYCTUS BEETLES—*continued.*

Name of preservative.	Absorption of preservative (lb./cu. ft.).	Starch content specimen.	Extent of damage to test specimens.
		ORGANIC.	
Chlorinated naphthalene (Halowax 1012)	0·02	Slight	Severe ; reinfested
	0·3	,, ...	Nil
	0·5	,, ...	,,
	1·0	,, ...	,,
	2·0	,, ...	,,
Chlorinated naphthalene (Seekay Wax R93)	0·025	Slight	Slight
	0·25	,, ...	Nil
	0·5	,, ...	,,
	1·0	,, ...	,,
	2·6	,, ...	,,
α–Chlornaphthalene	0·03	Slight	Severe
	0·3	,, ...	Trace
	0·7	,, ...	Nil
	1·3	,, ...	,,
	2·8	,, ...	,,
p–Dichlorphenol	0·03	Slight	Moderate
	0·3	,, ...	Severe
	0·7	,, ...	Nil
	1·3	,, ...	,,
	2·6	,, ...	,,
Sodium–2–chlor–o–phenylphenate	0·25	Slight	Moderate
	0·5	,, ...	Severe
	1·0	,, ...	Moderate
Sodium–o–phenylphenate ..	0·25	Slight to medium	Moderate
	0·5	Slight	,,
	1·0	,, ...	Severe
Sodium tetrachlorphenate ..	0·25	Slight	Slight
	0·5	,, ...	,,
	1·0	,, ...	Moderate
Tannic acid	0·2	Medium ..	Severe
	0·4	Dense	Moderate
	0·9	Medium ..	,,
	2·0	Dense	Slight
Lignasan (contains ethyl mercury chloride)	0·25	Slight	Nil
	0·5	Slight-medium ..	,,
	1·0	Slight	,,
745 A.B. (contains ethyl mercury phosphate)	0·25	Slight	Nil
	0·5	Medium ..	,,
	1·0	Slight	,,
745 A.C. (contains ethyl mercury chloride)	0·25	Slight	Nil
	0·5	,, ...	,,
	1·0	,, ...	,,

Table 4.—Results of Tests of Preservatives against Lyctus Beetles—*continued.*

Name of preservative.	Absorption of preservative (lb./cu. ft.).	Starch content specimen.	Extent of damage to test specimens.
		Controls.	
Untreated	..	Slight	Moderate
	..	,, ...	Severe
	..	,, ...	,,
	..	,, ...	Destroyed
	..	,, ...	Severe
	..	,, ...	Destroyed
	..	,, ...	Severe
	..	,, ...	,,
	..	,, ...	..
	..	,, ...	Moderate
	..	Medium ..	Severe
	..	,, ..	,,
	..	,, ..	Destroyed
	..	,, ..	,,
Water	..	Slight	Moderate
	..	Medium ..	Destroyed
	..	,, ..	,,
	..	,, ..	Moderate
	..	,, ..	,,
	..	,, ..	,,
Ethyl alcohol	..	Slight	Moderate
	..	Medium ..	Destroyed
	..	,, ..	,,
Benzol	..	Slight	Moderate
	..	Medium ..	Destroyed
	..	,, ..	,,

Thrips Investigation.

8. The Influence of Temperature on the Rate of Development of the Immature Stages of *Thrips imaginis* Bagnall and *Haplothrips victoriensis* Bagnall.

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(From the School of Agriculture, University of Melbourne.)

The work described in the following article forms part of the programme of investigations on thrips which is being carried out as a co-operative enterprise between the Thrips Investigation League, the Council for Scientific and Industrial Research, the Waite Agricultural Research Institute of the University of Adelaide, the University of Melbourne, and other bodies. Through the helpful co-operation of the University of Melbourne, laboratory accommodation and other facilities have been generously made available at the University's School of Agriculture, in connexion with the investigations in Victoria (see this *Journal*, **6**: 216, 1933). The article discusses work centred at that School.—Ed.

Summary.

This paper deals with the relationship of temperature and speed of development of the immature stages of *Thrips imaginis* and *Haplothrips victoriensis*. *Thrips imaginis* was taken from a laboratory colony. *Haplothrips victoriensis* was collected in the field.

Temperatures were kept constant to within $\pm 1^\circ$ C. Humidity was kept uniform at a saturation deficiency of 5 mm. of mercury throughout the temperature range, except for the incubation period of *T. imaginis*, where the atmosphere was saturated.

The relationship between temperature and rate of development is expressed as a straight line for both the incubation and post-embryonic development in the two species.

The "zero of the velocity curve" and "thermal constant" have been determined in each case.

1. Description of the Experiment.

The specimens of *Thrips imaginis* used in this experiment all belonged to different generations of the same laboratory stock which was originally started from about 50 individuals collected from roses in March, 1934. They have since been bred continuously at 23 deg. C. on rose buds from which all the petals were removed. The material for the work on *Haplothrips victoriensis* was collected at Kalorama (Vic.) from chrysanthemums in July 1934, and dahlias in February, 1935, and their progeny were used in these experiments.

Three kinds of temperature controls were used:—Firstly, the multiple–temperature incubator described by Andrewartha and Andrewartha (1935), which gave temperatures constant within $\pm 1^\circ$ C.; secondly, Hearson incubators which varied $\pm 0.5^\circ$ C.; thirdly, an ice-chest made of cork, which contained two compartments; it was placed inside a Hearson incubator at 25° C., and ice was placed in the upper compartment; the temperature in the lower compartment varied $\pm 1^\circ$ C. Each type of incubator which was used is indicated in the relevant tables by asterisks, &c.

* A Research Scholar of the University of Melbourne.

Humidity was controlled by saturated solutions of various salts*, which are listed in Table 1.

TABLE 1.—SATURATED SOLUTIONS OF SALTS USED TO GIVE A "SATURATION DEFICIENCY" OF 5 MM. OF HG.

Temperature in °C.	Percentage Relative Humidity.	Salts Used.
	%	
30	84	KCl
28	82	$(NH_4)_2SO_4$
23	76	$H_2C_2O_4$
21	74	$H_2C_2O_4$
19	70	NH_4Cl and KNO_3 together
17	65	NH_4NO_3
15	61	NaBr
12	51	$NaHSO_4$

Each compartment of the multiple–temperature incubator contained a suitable salt solution and was air-tight. In the Hearson incubators, the insects were placed in desiccators containing saturated salt solutions. The humidity of the incubator compartments was maintained uniform in this way at a saturation deficiency of 5 mm. However, the air inside the small vials containing the thrips was probably moister than this owing to the presence of the food.

The apparatus used to obtain the incubation period of *T. imaginis* is shown in Fig. 1. It consisted of a small cork with a hole bored through the centre. The upper part of the flower stem of *Plantago lanceolata* about 6 mm. long was fixed in this hole with plasticine, so that half protruded from each end of the cork. A small glass tube (4.0 x 0.6 mm.) with a cotton wool plug was pushed in over the upper

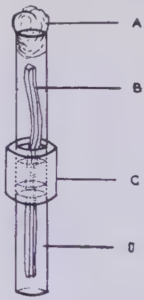

FIG. 1.—Apparatus used for obtaining the incubation period of the eggs of *T. imaginis*.

A. Cotton wool plug.
B. Stem of *Plantago lanceolata*.
C. Cork.
D. Glass vial for water.

end of the stem. A small glass vial about the same size containing water was pushed in the lower end of the cork. Females were allowed to oviposit in the plaintain for 12 hours at the higher temperatures and 24 hours at the lower temperatures, and then removed from the tube. Emergences were recorded, and nymphs removed every 12 hours at temperatures of 24.8° C., 22.5° C., 19.4° C., and 16.4° C., and every 24 hours at 11.5° C. and 11.1° C. Four to six of these cages were used at each temperature.

* In the case of the eggs of *T. imaginis*, a saturated atmosphere was maintained, since the eggs are laid in plant tissue and consequently develop normally in a saturated atmosphere.

The apparatus used for studying the post-embryonic period of *T. imaginis* and *H. victoriensis* consisted of glass vials (3.5 x 0.7 mm.) each closed by a cotton-wool plug. As the nymphs emerged, one nymph was placed in each numbered vial. The food consisted of one *Antirrhinum* (snapdragon) stamen per vial, which was renewed every day. The ecdyses from the nymphal to the pre-pupal, pupal, and adult instars were recorded with the aid of a binocular microscope. Emergences of adults were recorded every 12 hours for *T. imaginis* at the temperatures 24.8° C., 22.5° C., and 20° C., and for *H. victoriensis* at 26° C. It is realized that these intervals were rather too large, but it was not practicable to take readings at more frequent intervals.

Similar vials were employed to study the incubation period of the eggs and post-embryonic development of *H. victoriensis*. One adult was placed in each vial with a snapdragon stamen; the food was renewed every 24 hours. Frequent observations were made, and when the reddish eggs were seen the adult was removed and placed in a fresh vial and the vial containing the eggs was numbered.* Each nymph was removed when it emerged to a fresh vial, as otherwise it was liable to pierce and suck the remaining unhatched eggs.

2. Presentation of Data.

The data are summarized in Tables 2 to 5, and Figs. 2 and 3. Tables 2 and 3 deal with *T. imaginis* and 4 and 5 with *H. victoriensis*. With regard to the calculated values for standard error given in the tables, it should be noted that by reading the experiments at daily or half-daily intervals, the criteria for satisfactory fineness of grouping have not been satisfied. The standard error of grouping is $\frac{1}{\sqrt{12n}}$ in grouping units. For satisfactory fineness of grouping, this should not exceed one-tenth of the standard error of random sampling.

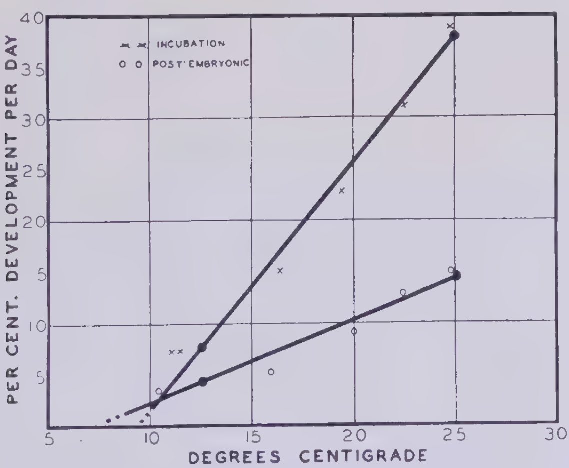

Fig. 2.—Curves showing "velocity of development" for the post-embryonic stages and incubation of the eggs of *T. imaginis*.

* The adults of this species nearly always lay their eggs on the surface of the cotton-wool plugs.

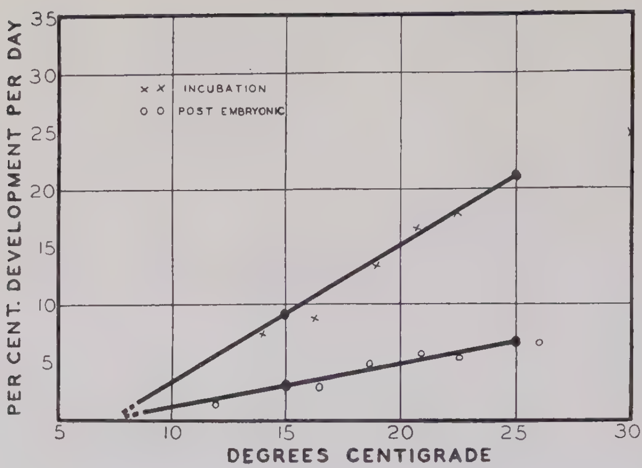

FIG. 3.—Curves showing "velocity of development" for the post-embryonic stages and incubation of the eggs of *H. victoriensis*.

TABLE 2.—THRIPS IMAGINIS (BAGNALL).

Temperature, °C.	Number of Individuals.	Incubation Period.		
		Mean Length in Days.	Standard Error in Days.	Percentage Development per Day.
				%
†24·8	36	2·58	±0·0707	38·7
†22·5	62	3·19	±0·0347	31·3
*19·4	51	4·39	±0·0319	22·7
*16·4	36	6·66	±0·0481	15·0
‡11·5	43	13·37	±0·1274	7·4
‡11·1	21	13·42	±0·1856	7·4

TABLE 3.—THRIPS IMAGINIS (BAGNALL).

Temperature, °C.	Number of Individuals.	Percentage Survival.	Mean of Combined Nymphal Instars in Days.	Mean of Combined Pupal Instars in Days.	Total Post-embryonic Development.		
					Mean Length in Days.	Standard Error in Days.	Percentage Development in One Day.
		%					%
†24·8	28	82·3	3·77	3·07	6·80	±0·0912	14·7
†22·5	40	75·5	4·09	3·83	7·92	±0·0652	12·6
†20·0	27	58·7	5·74	5·02	10·76	±0·1120	9·2
*15·9	18	51·4	9·02	9·64	18·66	±0·2832	5·3
‡10·5	38	57·6	15·47	14·76	30·23	±0·5241	3·3

* Multiple temperature incubator. † Hearson incubator. ‡ Hearson incubator containing ice-chest.

TABLE 4.—HAPLOTHRIPS VICTORIENSIS (BAGNALL).

Temperature, °C.	Number of Individuals.	Incubation Period.		
		Mean Length in Days.	Standard Error in Days.	Percentage Development per Day.
				%
†30·0	26	4·04	±0·1270	24·7
†22·5	64	5·59	±0·1098	17·8
*20·7	49	6·06	±0·1347	16·5
*18·9	44	7·45	±0·1419	13·4
*16·3	23	11·48	±0·2118	8·7
†14·0	44	13·52	±0·1174	7·3

TABLE 5.—HAPLOTHRIPS VICTORIENSIS (BAGNALL).

Temperature, °C.	Number of Individuals.	Percentage Survival.	Mean of Combined Nymphal Instars in Days.	Mean of Combined Pupal Instars in Days.	Total Post-embryonic Development.		
					Mean Length in Days.	Standard Error in Days.	Percentage Development in One Day.
		%					%
†26·0	37	77·1	9·55	4·98	14·53	±0·1857	6·8
†22·5	34	91·9	11·02	6·78	17·80	±0·2790	5·6
*20·8	29	80·6	11·07	7·41	18·48	±0·1663	5·4
*18·7	29	90·6	13·41	8·76	22·17	±0·2625	4·5
*16·5	18	81·8	21.00	13·77	34·77	±0·3730	2·8
‡12·0	41	82·0	32.41	19·51	51·92	±0·3948	1·9

* Multiple-temperature incubator. † Hearson incubator. ‡ Hearson incubator containing ice-chest.

In Figs. 2 and 3 the relationship between the rate of development—that is, per cent. development in one day—and temperature with *T. imaginis* and *H. victoriensis* has been expressed by straight lines which were obtained by calculating the regression of per cent. development on temperature. The observed mean values have been plotted as well as the theoretical curve.

3. Discussion of Results.

The observed mean values deviated from a straight line in a uniform manner for each of the four cases. The data were tested by Fisher's method for the Analysis of Variance (see Tables 6 to 9).

TABLE 6.—THRIPS IMAGINIS (BAGNALL).—INCUBATION PERIOD—ANALYSIS OF VARIANCE.

Source of Variance.	Degrees of Freedom.	Sum of Squares.	Variance or Mean Square.
Within arrays	223	4,784	21·45
Linear regression	1	27,158	27,158
Deviations from regression	3	851	283·66
Total	227	32,793	

$$Z = \tfrac{1}{2} \log_e \frac{283 \cdot 66}{21 \cdot 45} = 1 \cdot 290.$$

TABLE 7.—THRIPS IMAGINIS (BAGNALL).—POST-EMBRYONIC DEVELOPMENT—ANALYSIS OF VARIANCE.

Source of Variance.	Degrees of Freedom.	Sum of Squares.	Variance or Mean Square.
Within arrays	146	79	0·5411
Linear regression	1	2,756	2,756
Deviations from regression	3	83	27·6
Total	150	2,918	

$$Z = \tfrac{1}{2} \log_e \frac{27 \cdot 6}{\cdot 541} = 1 \cdot 966.$$

TABLE 8.—HAPLOTHRIPS VICTORIENSIS (BAGNALL).—INCUBATION PERIOD—ANALYSIS OF VARIANCE.

Source of Variance.	Degrees of Freedom.	Sum of Squares.	Variance or Mean Square.
Within arrays	244	1,388	5·688
Linear regression	1	7,132.8	7,132·8
Deviations from regression	4	182.058	45·514
Total	249	8,703	

$$Z = \tfrac{1}{2} \log_e \frac{45 \cdot 514}{5 \cdot 688} = 1 \cdot 04.$$

TABLE 9.—HAPLOTHRIPS VICTORIENSIS (BAGNALL).—POST-EMBRYONIC PERIOD—ANALYSIS OF VARIANCE.

Source of Variance.	Degrees of Freedom.	Sum of Squares.	Variance or Mean Square.
Within arrays	182	28·504	0·1566
Linear regression	1	583·817	583·817
Deviations from regression.. ..	4	14·489	3.644
Total	187	626·793	

$$Z = \tfrac{1}{2} \log_e \frac{3 \cdot 644}{0 \cdot 1566} = 1 \cdot 574.$$

In all cases, the value calculated for Z lies outside the 1 per cent. point of the distribution of Z. Therefore the mean variance due to deviations from regression is significantly greater than the mean variance within the temperature arrays. Nevertheless, the linear regression accounts for by far the greater proportion of the total variance, whereas variance due to random errors (within arrays) is small. Consequently, it is unlikely that any other type of curve would provide a better fit.

In Tables 3 and 5, percentage survival at the various temperatures has been included. With *H. victoriensis,* this varied from 77.1 to 91.9 per cent., and temperatures did not appear to affect the survival. With *T. imaginis,* on the other hand, the viability was higher at the higher temperatures; this may be due, in part at least, to the greater length of life at the lower temperatures, and the consequent greater amount of handling. The " zero of the velocity curve "* differs for the two periods studied. With *T. imaginis,* it was 9.30° C. for the incubation period, and 7.02° C. for the post-embryonic period.† The " thermal constants " were calculated from the formula $K=d\ (t\text{-}c)$, where K is the thermal constant, d is the development in days, t is the temperature in °C., and c is the zero of the velocity curve. The thermal constant for the embryonic development of *T. imaginis* was found to be 41.3 day degrees Centigrade; for the post-embryonic development, 125.5 day degrees Centigrade.

With *H. victoriensis,* the " zero of the velocity curve " for the incubation period lies very close to that of the curve for post-embryonic development. They are 7.21° C. and 6.80° C. respectively. The thermal constant for the embryonic development is 85.2 day degrees Centigrade, and for the post-embryonic is 275.1 day degrees Centigrade. Field observations of these two species in Adelaide showed that *H. victoriensis* does not reach its maximum as early in the summer as *T. imaginis* (Evans 1935). The numbers of the latter reached their maximum in November and December in 1932-35, and then fell rapidly away. The populations of *H. victoriensis* were highest during December, January, and February in 1932-35. As the " zero of the velocity curve " for the post-embryonic period of the two species is practically the same, the difference in their behaviour must be due either to the relatively slower development of *H. victoriensis* (thermal constant 85.2 + 275.1 day degrees Centigrade) compared with *T. imaginis* (thermal constant 41.3 + 125.5 day degrees Centigrade), or to factors other than their different temperature requirements.

4. Acknowledgments.

I wish to thank Miss F. E. Allen, Biometrician of the Council for Scientific and Industrial Research, for her assistance in the statistical analysis of this data, and Dr. J. Davidson for helpful criticism and assistance. Mr. G. Leeper advised me concerning the use of suitable salts. The figures were drawn by A. Mills.

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* Known as the " developmental zero " by some authors, it is the point at which the temperature axis is intersected by the curve of velocity of development.

† These figures do not coincide with those given by Evans (1932) and (1933). In the former paper, Evans combined embryonic and post-embryonic developmental periods, and drew a velocity curve which intersected the temperature axis at 7.97 deg. C. As there is no reason to expect that the speed of development should be uniform throughout the various stages of development, it is not surprising that the curve drawn for the complete developmental period should not coincide with those in the present paper, which relate to the incubation period, and the post-embryonic periods separately. In the latter paper, Evans analysed the same set of data again, this time separating the incubation period from a period which he described as " egg-hatching to egg-laying." This is a composite period which includes the " post-embryonic period" as defined in this paper, and a pre-oviposition period; consequently, the curve drawn for it is not comparable with the curve drawn to express post-embryonic development as studied in my experiments. The analysis of the incubation period defined by Evans is comparable with the one given here; the developmetal zero for this period is stated to be 6.6 deg. C., which is 2.7 deg. C. lower than the value obtained for my experiments. As the incubation period is relatively short, a serious error may have been introduced by reading the results at daily intervals. In the experiments dealt with in the present paper, an attempt was made to avoid this source of error by reading the results at twelve hourly intervals, and by using as many insects as practicable.

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A Note on the Effect of Green Manuring on the Water-Holding Capacity of Soils.

By Eric S. West, B.Sc., M.S.,* and A. Howard, M.Sc.†

Summary.

Nine years of continued use of green manure has increased the sticky point of the top 30 cms. of the soil by about 1.25 per cent. (of oven-dry weight of soil). This represents an increase in the field capacity of the soil as a whole, equivalent to about 6 mms. (0.25 inches) of rain, so that green manuring under these conditions is of little importance from the point of view of increasing the water-holding capacity of the soil. Its beneficial effects lie in other directions.

1. Introduction.

It is a well recognized fact that the water-holding capacity of humus or partly decomposed organic matter is very high when compared with the mineral matter of soils. Thus, on the basis of the oven-dried material, soil humus may have a water-holding capacity of the order of 200 to 300 per cent., or in the case of some "humus" extracts even up to 1000 per cent., compared with 20 to 40 per cent. for mineral clay soils.

For this reason, any method of adding organic matter to the soil, such as green manuring, may be expected to increase the soil's water-holding capacity. However, a consideration of the small amount of organic material left in the soil after the first rapid decomposition has taken place, compared with the total bulk of the root zone of the soil (about 4,000 tons per acre for a root zone of 2 feet depth) would lead one to expect that this increase in the water-holding capacity of the soil, following on the successive ploughing-in of green crops annually, is probably rather small.

2. Experimental.

Incidental to an investigation concerning the soil nitrate relationships of green manuring, data which throw some light on this question have been collected.

One replication of plots on the green manure field at this Station has had heavy crops of tickbeans growing during the winter since 1925. The crops which have been ploughed under in the spring have returned about 3 to 6 tons of dry matter each to the soil per acre. Another replication has been kept continuously clean-cultivated.

During 1933 and 1934, samplings were taken over these plots. Incidental to chemical analyses, the sticky points of the samples were determined. The sticky point gives an excellent idea of the field capacity of the soil.‡ The sampling for each replication was carried out in twelve positions, and the sampled material bulked and duplicate sub-samples taken, on which the determinations were carried out.

Sixty-eight duplicate determinations for each treatment are available.

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‡ West, E. S., *J. Agric. Sci.*, 21: 799-805, 1931.

The following table summarizes the results :—

Depth. (Cms.)	Sticky points of Soil in—		Difference.	Standard Error of Difference of Means.	Difference Expressed as mms. of Rain.
	Tickbean Plots.	Clean Cultivated Plots.			
0– 10	15·86	14·29	1·57	·14	2·4
10– 20	16·29	15·04	1·25	·20	1·9
20– 30	21·17	19·98	1·19	·26	2·1
30– 60	25·59	26·10	– 0·51	·26	
60– 90	23·61	24·17	– 0·56	·18	
90–120	22·71	23·25	– 0·54	·18	

The total increase in the field capacity of the soil due to the continued use of green manure is equivalent only to about 6 mms. (0.25 inches) of rain, or the increase represents about 50,000 lb. of water per acre. This figure is of the order that one might expect from a rough calculation of the amount of organic matter left by nine green crops, and a consideration of the water-holding capacity of this added organic matter.

The influence of the green manure is confined to the first 30 cms. of soil, as one would expect. The slightly lower sticky points of the tickbean plots below 30 cms. is just significant, and must be explained by assuming that the mean of the soil texture of the tickbean plots is slightly lower than that of the clean-cultivated plots. That the difference in the mean soil texture of the two plots is only of the order of 2 per cent. is very satisfactory, and shows that the soil variation has been largely overcome.

These results show that, under the conditions obtaining, the increase in the water-holding capacity of the soil brought about by continued green manuring is of little practical significance.

It must be clearly understood that we are dealing here with the effect of green manuring on the amount of water retained by the soil after it has been wetted by sufficient rain or irrigation water. This is entirely distinct from any effects of green manuring on the structure of the soil, on the permeability of the soil, or on the fertility of the soil.

A Note on the Development of *Echinococcus granulosus.*

By I. Clunies Ross, D.V.Sc.*

Summary.

(1) In 43 days, no mature *E. granulosus* were developed, the first evidence of egg production being obtained on the 47th day.

(2) Nemural, though effective in removing large numbers of *E. granulosus* and all gravid segments, failed to remove a considerable proportion of scolices.

In a previous report† evidence was obtained that development of *Echinococcus granulosus* occupied from 48 to 51 days. This period is of considerable importance since in dogs freed from *E. granulosus* by treatment but exposed to risk of re-infection, it will determine the intervals at which re-treatment should be carried out.

In the present experiment two dogs were infected with large doses of "hydatid sand" on 3rd September. The faeces of these dogs were examined daily from the 40th day onwards. After 43 days Dog (1) was autopsied and many thousands of *Echinococcus granulosus* collected from the small intestine. Microscopic examination of these failed to reveal any evidence of developed ova, while the faeces of both animals up to this date had been negative for Taenia eggs. The faeces of Dog (2) were examined daily until the 47th day, when the first Taenia egg was recovered by the glycerine flotation method for the concentration of eggs. On this occasion only a single egg was recovered from a gramme of faeces. In the succeeding days eggs became more numerous, and on the 51st day the animal was treated with Nemural, a Bayer proprietary taeniafuge. Many thousands of *E. granulosus* were recovered following treatment, and large numbers of these showed fully gravid segments containing eggs.

It is seen that the passage of eggs in the faeces occurred one day earlier than had previously been noted, while four days before this no evidence of egg formation could be detected. It appears, therefore, that the minimum period of development of adult *Echinococcus granulosus* is certainly more than six weeks and probably in most instances approximately seven weeks.

The Efficiency of Nemural against Echinococcus.

It has previously been shown (Clunies Ross, loc. cit.) that arecoline hydrobromide is a very efficient anthelmintic against *E. granulosus.* The opportunity was taken of testing the efficiency of Nemural. Dog (2), which was a small fox terrier weighing approximately 20 lb., was treated on the 51st day with two tablets of Nemural, this being slightly above the dose rate prescribed for a dog of this size. Thorough purgation occurred in 15 minutes, many thousands of *Echinococcus granulosus* being passed. Microscopic examination of these showed

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† Clunies Ross, I. Observation on the hydatid parasite (*Echinococcus granulosus*) and the control of hydatid disease in Australia. Coun. Sci. & Indust. Res. (Aust.), Bull. 40, 1929.

that great numbers of them had been passed intact, including the scolex, though some gravid segments without scolices were also passed. From a rough sampling of a portion of the worms passed it was estimated that not less than 20,000 *E. granulosus* had been passed following treatment. Three days subsequent to treatment faecal examination of this dog was negative for all Taenia eggs.

The dog was autopsied four days after treatment and the small bowel thoroughly examined for *E. granulosus.* Considerable numbers of scolices were found to be still present and viable, these by careful sampling being estimated at 3,100. No gravid segments were present upon any worm, thus accounting for the absence of eggs on faecal examination.

It is seen, therefore, that though Nemural was effective in removing a large number of Echinococcus, including gravid segments, a considerable proportion of scolices remained. The efficiency in this case was lower than that previously determined for arecoline hydrobromide, which was 100 per cent. effective in 4 cases and from 98—99.5 per cent. in two other cases. This observation indicates also the danger of assuming the absence of eggs following treatment to be due to the removal of all worms rather than to the elimination of all gravid segments. Such an animal might pass eggs in the faeces in well under seven weeks.

NOTES.

The Chinese National Agricultural Research Bureau.

Copies of the above Bureau's Miscellaneous Publication No. 4 entitled "History and Scope of Work" (written in English) recently reached Australia.

The Bureau is attached to the Ministry of Industries. It has been provided with an area (2,300 mow = about 380 acres) of land outside the city of Nanking. In addition, a headquarters building for "offices and laboratories and a dormitory" has been erected; it was first occupied in October, 1934. The building is of modern construction and equipped with steam heat, running water, &c.

The scientific work of the Bureau is organized into three Divisions, namely, the Divisions of Crop Production, Animal Production, and Agricultural Economics. These main Divisions have separate "Departments," depending on the need and on the funds and personnel available for the work. At the present time, the Division of Crop Production has four Departments: Agronomy, Forestry, Plant Pathology and Entomology, and Soils and Fertilizers. The Division of Animal Production is sub-divided into a Department of Sericulture and a Department of Animal Husbandry and Veterinary Science. The Division of Agricultural Economics is composed of a Department of Crop Reporting, a Department of Farm Management, and a Department cf Rural Industries.

An extract from the publication reads as follows:—

> "As it is recognized that soil and climatic factors have a great influence on the production of crops, and that varieties differ in their reaction to environmental conditions, it is planned that the crop improvement work will be conducted in co-operation with a number of stations. Despite the brief existence of the Bureau, co-operation has already been established and material is being grown in different localities throughout the country."

Then follows a list of co-operating stations. For the cotton improvement project alone, 17 organizations, e.g., the Provincial Wheat Experiment Station, Hsuchow, Kiangsu, and others of such like are named.

The work of the Bureau to date relates to such matters as wheat improvement, rice improvement, cotton improvement, potato improvement, the control of plant diseases and insects, soils and fertilizers, forestry, sericulture, the control of animal diseases, tea improvement, &c. Considerable advances have been made in some of the investigations, e.g., an extract *re* locust work reads as follows:—

> "Locust (*Locusta migratoria* L.) Control.—An investigation made by the Bureau in 1933 indicates that two hundred and sixty-five hsiens located in the provinces of Kiangsu, Chekiang, Anhwei, Shantung, Hopei, Honan, Hunan, Shensi, and Shansi suffered locust outbreaks during that year, the crop damage amounting to $14,000,000. Considerable attention, therefore, is being given to the problem of controlling locusts, the importance of which is undoubtedly known to every one. The

complete life history of the locust has been studied, and the general distribution of this insect as well as the direction of its migrations has been learned. It is the intention of the Bureau to establish field stations in the regions where locusts are causing serious damage and to promote a control campaign in co-operation with the Provincial Governments."

As to the future programme, it is recognized that it will never be possible for the Bureau at any one time to have a large enough staff to work on all the problems important to agriculture, but it is intended to take up the more important matters with the hope of solving them first. Another extract from the publication on this point reads as follows:—

"It is only through combined co-operative effort that the large nation-wide or regional problems can be solved, and it is hoped that as time goes on the Bureau will more and more take a lead in helping develop this co-operation. It is intended that the Bureau shall serve the whole nation. While it is necessary to have the large central farm at one place, the officials of the Bureau nevertheless recognize the importance of conducting many of the experiments in regions far removed from Nanking."

The results obtained by the Bureau are published in a journal—*Agricultura Sinica*—in a series of special publications and circulars, and in a series of miscellaneous publications. For presenting more popular information, an agricultural newspaper, the *Nung Pao*, is issued every ten days.

Fundamental Research by the U.S. Department of Agriculture.

According to a recent number of *Science*, a Bill has recently been passed in the United States of America authorizing and directing the United States Secretary of Agriculture to conduct research into the laws and principles underlying basic problems of agriculture in its broadest aspects, and also to carry on investigations looking to improvements in handling and marketing, as well as research relating to the conservation and development of land and water resources for agricultural purposes. The work thus contemplated is to supplement and not to replace other researches now being conducted under the aegis of the Department of Agriculture.

The initial funds for this work will amount to $1,000,000. This sum will be increased by an additional $1,000,000 each year until the total reaches $5,000,000, and thereafter the special research fund will be maintained at the latter sum each year. Forty per cent. of the total amount in any one year is to be expended under the direct supervision of the Secretary of Agriculture, in any places and for any research purposes he may approve. The remaining 60 per cent. will be allocated to State agricultural experiment stations according to the size of their respective rural populations. Funds thus allocated, however, must be matched dollar for dollar by the States receiving them.

The establishment of new laboratories is within the authorizations of the Act, since it is provided that funds may be used for the erection of buildings and the purchase or rental of land needed for the purpose.

Developing the Pre-fabricated House.

(*Contributed by the Division of Forest Products.*)

In recent years, the pre-fabricated house has been seriously considered by both the manufacturer and the house buyer. At the present time, in the United States alone, the research workers and engineers of more than 40 companies are actively engaged investigating the design and construction of a factory-made house which can be erected at a lower price and yet meet the exacting demands of the purchasing public. These companies have realized that radical changes in accepted materials and construction are necessary before building costs can be appreciably reduced.

Aluminium and steel figure prominently in this development. Houses have already been erected in which ribbed aluminium or steel sheets are secured to a light structural framework of 16-gauge steel channel sections and bracing welded together. In another design, a fabricating system has been exploited in which the various members slide together and are secured by clips so that bolts and welded joints are eliminated. In yet another design, the structural framework has been entirely eliminated by using interlocking panels of a heavier gauge sheet of metal. Floor and ceiling joists are of trussed steel or light steel channel sections.

The possibilities of using concrete have also been investigated. Large pre-cast concrete wall panels have been fitted in between reinforced concrete studs which have been poured *in situ*. Attempts have been made to give the natural finish of these panels a decorative effect by using coloured aggregate in the concrete.

It is interesting to study the contribution that wood has made towards the satisfactory solution of this problem. The energetic research and advertising campaign to extend the market for cement and various sheet metals and alloys is due to the support of several immense manufacturing corporations. Unfortunately, until quite recently the various trade organizations representing the timber producers have not given wood the same amount of publicity. Besides having decorative and insulating properties, wood has many other properties which make it particularly well suited for use in a pre-fabricated house. In the majority of schemes which have already been prepared, plywood has been used for both the interior and exterior surfaces. The plywood panels are joined together by splines, bolts, or else fitted into the flanges of a light structural steel framework. Similar units are used for both the floor and the ceiling where a flat roof is required, and when the house has been designed having a sloping roof, light trusses and timber connectors have been used. The Forest Products Laboratory at Madison, Wisconsin, U.S.A., has recently designed and constructed a pre-fabricated house. It represents a system of construction which is still being investigated, and its development was made possible only as the result of recent research into the uses of timber in construction.

The basic structural unit of the majority of pre-fabricated houses is the panel, and plywood is particularly well suited as a material to be used for the interior and exterior surfaces of the panel. Plywood gives a large unbroken surface which shrinks less and yet is considerably stronger than solid wood of the same size. Hot-press synthetic glues can be used in the manufacture of the plywood which makes a joint

which is waterproof. Each panel consists of two plywood faces glued to either side of an inner structural framework to form a unit similar to a box girder. Contrasted with ordinary frame construction, stressed coverings give much higher strength and rigidity values with a minimum of material. For example, flooring boards are usually nailed to relatively deep joists, and they do not materially increase the strength of the joists. Similarly, ceilings fixed to the underside of floor joists are additional dead weight. In the panel developed by the United States Forests Products Laboratory at Madison, the weight is distributed by the joists to the plywood faces so that the joists actually support only about one quarter the load. This unity of action is due to the complete and continuous rigid joint formed by the glue between the plywood faces and the joists. Such a joint can not be produced by nailing.

The wall panels are constructed of $\frac{1}{4}$-in. 3-ply glued on to $\frac{3}{4}$-in. x $1\frac{3}{8}$-in. battens, which gives a total wall thickness of $1\frac{7}{8}$ inch. Vertical mullions are used to secure the panels and they are set in a suitable mastic which protects the edges of the plywood from moisture and prevents the infiltration of air. The natural finish of the plywood is used for the interior wall surfaces and the exterior surface is given two coats of aluminium priming and then painted.

The design of this all-wood pre-fabricated house is probably the most scientific and satisfactory solution to the problem that has yet been offered. However, at present, it appears that the pre-fabricated house is still in the experimental stage.

It must be appreciated that there are many difficulties which have to be overcome before the ideal pre-fabricated house is evolved. The problem is attracting a lot of attention in America and the Continent, and it is reasonable to expect that in a few years the factory-made house will be an accomplished fact.

The New Zealand Department of Scientific and Industrial Research.

Copies of the 9th Annual Report of the New Zealand Department of Scientific and Industrial Research have recently become available in Australia. A number of investigations of interest to Australian industries are in progress. A brief outline of the Department's work and organization is given in the paragraphs that follow.

The Dairy Research Institute is devoting much attention to problems of butter and cheese. Attempts to manufacture ghee are a new direction in which the Institute hopes to help the industry in an effort to find an outlet for dairy products. Next season an extended investigation into the variations in the composition of butter-fat in New Zealand in relation to feed, breed, and period of lactation will be undertaken. It is considered that the keeping quality, spreadability, and vitamin content are related to the composition of the fat, but little is known with regard to the relation of these factors to one another.

The Plant Research Station is situated at Palmerston North, and is conducted in co-operation with the Department of Agriculture. The Station comprises a number of sections such as the botanical section, chemical section, field experimental work, mycological laboratory, agrostological section, and the agronomy section.

The Wheat Research Institute is devoting much attention to quality of wheat and to the breeding of wheat. The latter work is directed

towards the discovery of a wheat which will yield as well as Tuscan and yet be of higher quality so as to eliminate the present practice of importing Canadian flour. At the Massey Agricultural College a programme of work concerning *Phormium tenax* (New Zealand flax) is in progress. Such work includes the selection, testing, and propagation of varieties; diseases of the plant are also being studied.

Work on the mineral content of pastures is in progress at the Cawthron Institute, and concerns such matters as bush sickness investigations, fertilizer trials, the effect of leniency of cutting on yield, and soil phosphate studies.

Leather and pelt research is carried out with the co-operation of the industry. The work is really that of an Industrial Research Association. Matters recently under examination are the leaching of bark, the wearing of sole leathers, and the oiling of sole leathers. Some of the results of the work on pelts have been tested in actual practice by means of trial shipments.

The fruit research programme has continued as a co-ordinated activity, the participating bodies being the Plant Research Station, the Cawthron Institute, the Horticulture Division of the Department of Agriculture, and the Department of Scientific and Industrial Research. The work is also helped by assistance given by the industry. An experimental orchard has been established for the conduct of manurial, spray, and cultural trials. It is also available for field studies arranged by any workers engaged on allied researches. Attention is also given to insect pests such as the woolly aphis, pear midge, the leaf hopper, &c.

Fruit cold storage research is being carried out in cool stores in Wellington, Nelson, and aboard selected transporting vessels.

The Department is interested in a programme of soil surveys of different districts. During the last year, attention was given to the soil types of localities in which one or two diseases of animals occur.

Tobacco Investigations—Work on Physiological Aspects.

Arising partly out of the chemical work which Professor Earl and Mr. Hall are carrying out on tobacco at the University of Sydney (see this *Journal* **8**: 277, 1935), arrangements have now been made for some physiological work to be commenced, particularly with respect to the translocation of nitrogen and possibly other nutrients in the tobacco plant. The investigations will form a part of the general attack on the development of methods whereby to improve the quality of Australian tobacco.

The new work will be carried out by the Waite Agricultural Research Institute, where it will be under the immediate supervision of Dr. A. H. K. Petrie, of the Institute's staff. Two assistants for Dr. Petrie have recently been appointed. They will be financed from the Council for Scientific and Industrial Research portion of the Commonwealth Government's grant of £20,000 per annum for tobacco investigations.

Irrigated Pastures at Merbein.

Some time ago, the Advisory Committee of the Council's Viticultural Station at Merbein made representations for the establishment of pasture plots on the Station. It was considered that many settlers in fruit-producing areas could with advantage put down in grass those portions of their holdings which are unsuitable for horticultural plants, and that certain marginal lands adjacent to the irrigation settlements may possibly be of value for fodder production.

To study the suitability of various grasses, two series of small plots were designed by Professor A. E. V. Richardson and Dr. B. T. Dickson. The seeds were sown at Merbein according to plan in September, 1935, and the grasses in the various plots are now in their first year of growth.

Book Review.

"Insect Pests of Glasshouse Crops," by H. W. and M. Miles. [H. C. Long, Surbiton, Surrey. 1935].

Although this useful reference book is concerned with pests in English glasshouses, much of the information given is definitely of use to Australian horticulturists, nurserymen, and amateur gardeners. Many of the pests described are the same as, or closely related to, our common garden pests.

The treatment of the subject-matter is essentially clear and practical, particular attention being devoted to control measures. The authors have been careful to recommend only simple and up-to-date methods of control based on their own practical experience.

This book, of 174 pages, contains many excellent photographs, and it is of interest to note that the frontispiece illustrates a parasite (*Encarsia formosa*) recently introduced into Australia by the Council to control the greenhouse white fly.

—A. J. Nicholson.

Recent Publications of the Council.

Since the last issue of this *Journal,* the following publications of the Council have been issued:—

Bulletin No. 93.—"Studies on Contagious Pleuro-pneumonia of Cattle. I. A Study of the Morphology and Life Cycles of the Organism of Pleuro-pneumonia Contagiosa Boum (*Borrelomyces peripneumoniae* nov. gen.) by Observation in the Living State under Dark-ground Illumination," by A. W. Turner, D.Sc., D.V.Sc.

This Bulletin consists of a reprint of a comprehensive article which has already appeared in the *Journal of Pathology and Bacteriology*. It contains the results of work carried out by Dr. Turner at the Animal Health Research Station, Oonoonba, near Townsville, Queensland, as part of the investigations which are centred at that Station and being carried out as a co-operative enterprise of the Queensland Department of Agriculture and Stock, the Queensland Council of Agriculture, cattle-owners of Queensland, and the Council for Scientific and Industrial Research.

The report deals with the various forms assumed by the causal organism of contagious pleuro-pneumonia in an artificial culture medium and in the inflammatory exudate. For many years, this organism has been classed amongst those minute forms of life, smaller than bacteria, invisible when examined by ordinary technique under the microscope, incapable of being grown under artificial conditions suitable for the cultivation of bacteria, and capable of passing through filters which hold back the smallest bacteria, and therefore called either filterable viruses or ultra viruses. A thorough knowledge of the organism—a knowledge which has now been extended by Dr. Turner—forms a necessary foundation on which to build information concerning its relationship to the host, and thus information that may lead to its easy control.

Pamphlet No. 59.—"A Study of Persistence in Certain Introduced Pasture Grasses," by A. McTaggart, M.S.A., Ph.D.

Data obtained systematically from persistency trials with 21 recently-introduced grasses are presented in tabular form. As the result of preliminary tests, these species and strains had been chosen for sward investigations because they appeared to be the most promising for different conditions in Australia. Notes on the palatability of these grasses to sheep are presented, and the plants have been classified according to their varying reaction to differential sward treatment and their differing capacities to withstand close grazing and still maintain themselves in the pasture.

Pamphlet No. 60.—"A Report on a Survey of Weed Problems in Australia," by G. A. Currie, B.Sc., B.Agr.Sc.

For some time past, the problem presented by noxious weeds in Australia has been under consideration by the Standing Committee on Agriculture—a body of the Australian Agricultural Council—and independently by several of the bodies represented on it. One result was an arrangement that, as a preliminary to further work, an officer of the Council should make a survey of the extent of the problem, the economic importance of different weeds, and methods of control that had been tried in an endeavour to cope with them effectively, this report to include recommendations for further co-operative work. This survey was in due course carried out by Mr. G. A. Currie, and has been published in a slightly abridged form in the present Pamphlet. Sixteen weeds, namely, Noogoora burr, Bathurst burr, bracken, galvanized burr, stinkwort, thistles, blackberry, Cape tulip, St. John's wort, lantana, ragwort, skeleton weed, convolvulus, wild turnip, hoary cress, and nut grass, were selected as being the most important in Australia. Details of their economic significance and suggestions for lines of further investigation on each are given.

Forthcoming Publications of the Council.

At the present time, the following future publications of the Council are in the press:—

Bulletin No. 94.—"Fertility in Sheep: Artificial Production of Seminal Ejaculation and the Characters of the Spermatozoa Contained Therein," by R. M. C. Gunn, B.Sc. (Agric.), D.V.Sc., M.R.C.V.S. (Lecturer in Veterinary Anatomy, Surgery, and Obstetrics at the University of Sydney).

Bulletin No. 95.—"Radio Research Board: Report No. 9." 1. A Study of the Magneto-Ionic Theory of Wave Propagation by Means of Conformal Representation, by V. A. Bailey, M.A., D.Phil., F.Inst.P. 2. Dispersion and Absorption Curves for Radio Wave Propagation in the Ionosphere according to the Magneto-Ionic Theory, by D. F. Martyn, Ph.D., A.R.C.Sc., F.Inst.P. 3. A Temperature Compensated Dynatron Oscillator of High Frequency Stability, by J. H. Piddington, B.Sc., B.E. 4. The Amplification of Programme Transients in Radio Receivers, by Geoffrey Builder, Ph.D., F.Inst.P. 5. A Multi-Range, Push-Pull Thermionic Voltmeter, by Geoffrey Builder, Ph.D., F.Inst.P. 6. The Graphical Solution of Simple Parallel-Tuned Circuits, by Geoffrey Builder, Ph.D., F.Inst.P. 7. An Electrical Harmonic Analyser of the Fundamental Suppression Type, by J. H. Piddington, B.Sc., B.E.

Bulletin No. .—"Radio Research Board: Report No. 10."

Bulletin No. .—"Studies in Bovine Pleuro-Pneumonia. II.—A Complement-fixation Reaction for the Diagnosis of Contagious Bovine Pleuro-Pneumonia, by A. D. Campbell, B.V.Sc., and A. W. Turner, D.Sc., D.V.Sc. II. (*a*) Observations on the Diagnosis of Contagious Bovine Pleuro-Pneumonia by means of the Complement-fixation Tests of Campbell and Turner, by H. R. Seddon, D.V.Sc. II. (*b*) The Complement-fixation Test of Pleuro-Pneumonia, by H. Albiston, D.V.Sc. III.—A Cultural Study of the Distribution of the Specific Organism, *Borrelomyees peripneumoniae,* Turner, 1935, throughout the Body of Animals Naturally and Artificially Infected," by A. D. Campbell, B.V.Sc.

Bulletin No. .—"A Survey of the Pastures of Australia—Embodying Ecological Information and Discussions Explanatory of the accompanying Pasture Map of the Commonwealth," by A. McTaggart, M.S.A., Ph.D.

Bulletin No. .—"Cercospora Leafspot (Frog-eye) of Tobacco in Queensland," by A. V. Hill, B.Agr.Sc.

Pamphlet No. 61.—"A Discussion of Special Tests on the Compressive Strength of Green Karri (*Eucalyptus diversicolor*)" (Division of Forest Products—Technical Paper No. 19), by Ian Langlands, B.E.E.

Pamphlet No. .—"Studies of Five Introduced Grasses suitable for the Mediterranean Zone," by A. McTaggart, M.S.A., Ph.D., W. Hartley, B.A., T. B. Paltridge, B.Sc., and H. K. C. Mair, B.Sc.

H. J. Green,
Govt. Printer, Melbourne.